Ministry of
Northern Development
and Mines

Ontario

Mines and
Minerals
Division

Precambrian Geology
Monument Bay Area
Lake of the Woods

Ontario Geological Survey
Report 265

M.G. Morrice

1989

CANADA ONTARIO

This project is part of the five-year Canada-Ontario 1985 Mineral Development Agreement (COMDA), a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

90-01851/

© 1989 Queen's Printer for Ontario
Printed in Ontario, Canada
ISSN 0704-2582
ISBN 0-7729-5663-4

Publications of the Ontario Geological Survey and the Ministry of Northern Development and Mines are available from the following sources. Orders for publications should be accompanied by cheque or money order payable to the *Treasurer of Ontario*.

Reports, maps, and price lists (personal shopping or mail order):
Public Information Centre, Ministry of Natural Resources
Room 1640, Whitney Block, Queen's Park
Toronto, Ontario M7A 1W3

Reports and accompanying maps only (personal shopping):
Publications Ontario
Main Floor, 880 Bay Street
Toronto, Ontario M7A 1N8

Reports and accompanying maps (mail order or telephone orders):
Publications Ontario, Ministry of Government Services
5th Floor, 880 Bay Street
Toronto, Ontario M7A 1N8
Telephone (local calls), 965-5300
Toll-free long distance, 1-800-668-9938

Canadian Cataloguing in Publication Data

Morrice, Martin Gray.

Precambrian geology, Monument Bay area, Lake of the Woods

(Ontario Geological Survey report, ISSN 0704-2582; 265)
ISBN 0-7729-5663-4

1. Geology--Ontario--Monument Bay Region. I. Ontario. Mines and Minerals Division. II. Ontario Geological Survey. III. Title. IV. Series.

QE1 91.M67 1989 557.1'3'11 C89-099631-8

Every possible effort is made to ensure the accuracy of the information contained in this report, but the Ministry of Northern Development and Mines does not assume any liability for errors that may occur. Source references are included in the report and users may wish to verify critical information.

If you wish to reproduce any of the text, tables or illustrations in this report, please write for permission to the Director, Ontario Geological Survey, Ministry of Northern Development and Mines, 11th Floor, 77 Grenville Street, Toronto, Ontario M7A 1W4.

Parts of this publication may be quoted if credit is given. It is recommended that reference be made in the following form:

Morrice, M.G. 1989. Precambrian geology, Monument Bay area, Lake of the Woods; Ontario Geological Survey, Report 265, 69p.

Scientific Editor: M.E. Grant
Maracle-1000-89

Foreword

Prior to 1987, geological information for the Monument Bay area of Lake of the Woods was at a reconnaissance level. The detailed mapping project described in this report was designed to encourage mineral exploration interest and to provide a basis for land use planning.

There is no known mineral production from the area and only limited base metal exploration reported. Several features make this an attractive region in which to conduct exploration for base and precious metals. Clasts of massive sulphide have been observed associated with felsic metavolcanic rocks, indicating a promising environment for base metals. Precious metal exploration should focus on shear zones which host quartz-carbonate-pyrite veins. A number of samples collected from such shear zones during the course of this project, contain over 100 parts ber billion gold; the highest value obtained is 52.3 parts per million.

This project is part of the Canada–Ontario Mineral Development Agreement (COMDA) which is a subsidiary agreement to the Economic and Regional Development Agreement (ERDA) signed by the governments of Canada and Ontario.

V.G. Milne

Director
Ontario Geological Survey

Contents

Abstract 2

Résumé 4

Introduction 6
- Location 6
- Access 6
- Physiography 6
- Field Methods 7
- Previous Geological Work 7
- Mining and Exploration History 7
- Acknowledgments 7

General Geology 8
- Introduction 8
- Metavolcanic and Metasedimentary Rocks 14
  - Tholeiitic Metavolcanic Rocks 14
    - Mafic to Ultramafic Metavolcanic Rocks 14
  - Alkalic (Shoshonitic) to Calc-Alkalic Metavolcanic Rocks 14
    - Mafic Metavolcanic Rocks 14
    - Intermediate Metavolcanic Rocks 17
    - Intermediate to Felsic Metavolcanic Rocks 18
  - Clastic and Chemical Metasediments 20
  - Intrusive Rocks 22
    - Metamorphosed Ultramafic Intrusive Rocks 22
    - Metamorphosed Mafic Intrusive Rocks 22
    - Metamorphosed Intermediate to Felsic Intrusive Rocks 22
    - Alkalic Intrusive Rocks 22
    - Intermediate to Felsic Intrusive Rocks 25
    - Mafic Intrusive Rocks 26

Geochemistry 27
- Introduction 27
- Metavolcanic Rocks 27
  - Tholeiitic Metavolcanic Rocks 27
    - Ultramafic and Mafic Metavolcanics 27
  - Alkalic to Calc-Alkalic Metavolcanics 27
    - Mafic Metavolcanics 27
    - Intermediate Metavolcanics 27
    - Intermediate to Felsic Metavolcanics 28
- Intrusive Rocks 28
  - Metamorphosed Mafic Intrusive Rocks 28
  - Metamorphosed Intermediate to Felsic Intrusive Rocks 28
  - Alkalic Mafic Intrusive Rocks 28
- Discussion 28

Structure, Metamorphism and Alteration 49
- Structure 49
- Metamorphism 52
- Alteration 54

Economic Geology 57
- Introduction 57
- Description of Properties 57

Hudson Bay Exploration and Development 57
Phelps Dodge Corporation of Canada Limited (2) 57
Discussion of Assay Results 57
Guidelines for Mineral Exploration 57
Base Metals 57
Gold 57
References 68

FIGURES

1. Key map showing location of the Monument Bay Area 6
2. Generalized geology of the Monument Bay Area. 8
3. K_2O versus SiO_2 diagram 10
4. Jensen cation diagram–tholeiitic metavolcanics 11
5. AFM diagram–tholeiitic metavolcanics 11
6. Map showing the distribution of informal formations 12
7. Map showing the locations of stained slabs of granitoids 24
8. Modal analyses of granitoid rocks on Quartz–Alkali Feldspar–Plagioclase ternary diagram 25
9. Locations of whole rock geochemistry samples 29
10. REE diagram–tholeiitic mafic to ultramafic metavolcanics 47
11. REE diagram–alkalic mafic metavolcanics 47
12. REE diagram–alkalic and calc-alkalic intermediate metavolcanics 48
13. REE diagram–alkalic and calc-alkalic intermediate to felsic metavolcanics 48
14. Map showing the trace of the amphibolite-greenschist facies metamorphic isograd and the distribution of alteration and high strain zones 53
15. Assay sample locations, Monument Bay area 58

PHOTOS

1. Pillowed and massive basaltic komatiites, South Bay formation, South Bay 15
2. Clinopyroxene phenocrysts (pseudomorphed by amphibole) in alkalic mafic pyroclastics, Monument Bay formation, Monument Bay. . 16
3. Flattened and "biotitized" clinopyroxene phenocrysts, Monument Bay formation, Monument Bay 16
4. Tabular plagioclase phenocrysts in mafic, plagioclase and clinopyroxene porphyry subvolcanic dike, Separation Point Formation, northeast of Separation Point. 17
5. Autoclastic clinopyroxene-phyric blocky flow, Monument Bay formation, Monument Bay. 18
6. Well-bedded clinopyroxene-phyric pyroclastics, Monument Bay formation, Monument Bay. 19
7. Ballistically emplaced, spindle-shaped, clinopyroxene-phyric volcanic bomb in clinopyroxene-phyric tuffs, Monument Bay formation, Monument Bay. 20
8. Scour-and-fill structure, and cross-bedding in clinopyroxene-phyric tuffs, Separation Point formation, Separation Point 21

9. High-potassium calc-alkalic plagioclase-phyric pillow breccia, Johnston Passage formation, south of La Vérendrye Island. 22
10. Coarse, bedded wackes, Royal Island formation, north of La Vérendrye Island 23
11. Microcline-megacrystic syenite, southeast part of map area 23
12. Sheared and carbonatized tholeiitic mafic metavolcanics within the Monument Bay deformation zone, north of Separation Point. . . 49
13. Quartz-carbonate-pyrite vein within a shear zone in mafic metavolcanics, north of Separation Point. 49
14. Minor sinistral offset of F_1 foliation along shear fracture, Drift Island formation, Drift Island. 50
15. Anastomosing shear fractures in intermediate to felsic sill caused by rotation of conjugate shear fractures, Drift Island formation. 50
16. Folded and migmatized metasediments, Betty Island formation, Ike Island. 51
17. Preferential alteration of hyaloclastic matrix of pillow breccia by hornblende and garnet; Johnston Passage formation, north of Falcon Island. 52
18. Amphibolitized, intermediate plagioclase-phyric pillowed flow, Johnston Passage formation, south of La Vérendrye Island 54
19. Intensely carbonatized, autoclastic, clinopyroxene-phyric mafic flow, Monument Bay formation, south of Outer Bay. 55

TABLES

1. Table of Lithologic Units for the Monument Pay Area. 9
2. Table of Formations for the Monument Bay Area. 13
3. Geochemistry of Mafic to Ultramafic Metavolcanics. 30
4. Geochemistry of Alkalic Mafic Metavolcanics. 33
5. Geochemistry of Intermediate Metavolcanics. 37
6. Geochemistry of Intermediate to Felsic Metavolcanics. 40
7. Geochemistry of Metamorphosed Mafic Intrusive Rocks. 43
8. Geochemistry of Metamorphosed Felsic to Intermediate Intrusive Rocks. 44
9. Geochemistry of Metamorphosed Alkalic Mafic Intrusive Rocks. 45
10. Descriptions of Whole Rock Geochemistry Samples 46
11. Assay Results 59
12. Anomalous Assay Results. 67

MAP (back pocket)

Map 2524—Precambrian geology, Monument Bay area, Lake of the Woods; scale 1:20 000.

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

***Note:** Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.*

Precambrian Geology Monument Bay Area

Lake of the Woods

M.G. Morrice

Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

Manu cript approved by A.C. Colvine, Chief Geologist, June 10, 1987. Report published with the permission of V.G. Milne, Director, Ontario Geological Survey.

Abstract

The Monument Bay area, which encompasses about 150 km², is about 50 km southwest of the town of Kenora. The area is part of the Lake of the Woods greenstone belt, an east-trending belt of metavolcanic-metasedimentary rocks which is located in the western part of the Wabigoon Subprovince of the Superior Province of the Canadian Shield. The area is bounded by latitudes 49°30′N and 49°22′N and longitudes 94°56′W and 94°47.7′W. All bedrock in the map area is inferred to be Archean in age, with the exception of north-northwest-trending Proterozoic diabase dikes.

Supracrustal rock units face south in the north half of the map area, while several facing reversals in the south part define tight folds. Most supracrustal rocks have a well-developed foliation which trends east to northeast, except where deflected around granitic plutons. Intensity of fabric development is heterogeneous.

Ninety percent of the map area is underlain by metavolcanics, five percent by metasediments and five percent by granitoids. The metavolcanics have been subdivided, both on textural and geochemical criteria, into alkalic (shoshonitic), calc-alkalic and tholeiitic associations. Alkalic and calc-alkalic volcanic rocks, which are about 80 percent of the metavolcanic rocks, range in composition from mafic to felsic. The remaining 20 percent of metavolcanics are tholeiitic basalts and basaltic komatiites. Alkalic basalts are mainly pyroclastic; individual clasts may be highly amygdaloidal and characteristically contain euhedral, calcic clinopyroxene phenocrysts (now largely pseudomorphed by amphibole). Tholeiitic basalts are invariably pillowed or massive flows, are non- to weakly vesicular, aphyric, and commonly variolitic.

Geochemistry supports the distinctiveness of these textural features. Alkalic basalts (SiO_2 less than 53 percent) have high K_2O contents (K_2O greater than 1 percent) and chondrite-normalized rare earth element (REE) patterns which show enrichment in light REE (LREE) ($(Ce/Yb)_N > 5$). On the other hand, tholeiitic basalts are low in K_2O (K_2O less than 0.3 percent) and have chondrite-normalized REE patterns which are flat, to slightly depleted, in LREE ($(Ce/Yb)_N < 1.5$). Calc-alkalic basalts are intermediate between these extremes.

Metasediments occur as minor conglomerates produced by local reworking of pyroclastics, interflow argillites and siltstones, and several prominent wacke horizons.

Intrusive rocks comprise synvolcanic, mafic to felsic sills; a suite of syn- to posttectonic alkalic intrusive rocks, including lamprophyre dikes and a syenite pluton; and two late-tectonic granodiorite plutons.

Peak metamorphic conditions reached amphibolite facies over the southwestern two-thirds of the map area, and greenschist facies over the remainder.

The supracrustal rocks have been variably altered. Two zones of hornblende-garnet alteration trend northeast across the map area, within amphibolite-grade assemblages. This alteration was traced into lower grade, greenschist facies rocks which are intensely carbonatized.

While there is no known past or present mineral production from the map area, several features make this an attractive area in which to conduct mineral exploration. The rocks with the most potential for base metal exploration are proximal, quartz-phyric, intermediate to felsic metavolcanics, especially west of Outer Bay where sulphide clasts are associated with these metavolcanics.

Gold exploration should be directed primarily at shear zones within mafic metavolcanics, especially in the region of extensive hornblende ± garnet and carbonate alteration.

The amphibolite-greenschist facies boundary crosses the two major hornblende-garnet or carbonate alteration zones at near right angles and should direct initial exploration for precious metals. A number of samples collected from quartz-carbonate-sulphide veins in shear zones in the mafic metavolcanics contain greater than 100 ppb gold, with the highest value obtained being 52.3 ppm gold.

Résumé

La région de Monument Bay qui couvre environ 150 km² est située à quelque 50 km au sud-ouest de la ville de Kenora. Cette région fait partie de la ceinture de roches vertes de Lake of the Woods, formée de roches métavolcaniques-metasédimentaires orientées vers l'est qui se trouvent dans la partie ouest de la sous-province de Wabigoon au sein de la province du Supérieur du Bouclier canadien. Elle est située entre 49°22′ et 49°30′ de latitude nord et entre 94°47,7′ et 94°56′ de longitude ouest. Le substratum rocheux dans la région cartographiée est considérée comme appartenant entièrement à l'Archéen, à l'exception de dykes diabasiques Protérozoïque d'orientation générale nord-nord-ouest.

Les unités rocheuses supracrustales font face vers le sud dans la partie nord de la zone cartographiée tandis qu'un certain nombre d'inversions dans la partie sud définissent des plis serrés. La plus grande partie des roches supracrustales présentent une foliation bien développée, orientée est-nord-est sauf aux voisinage des plutons granitiques ou celle-ci est déviée. La puissance de développement de la structure est variable.

La région cartographiée repose à 90 % sur des roches métavolcaniques, à 5 % sur des roches métasédimentaires et à 5 % sur des roches granitoïdes. Les roches métavolcaniques ont été subdivisées, selon des critères tant texturaux que géochimiques, en associations alcalines (shoshonitiques), calc-alcalines et tholéiitiques. La composition des roches volcaniques alcalines et calc-alcalines, qui représentent environ 80 % des roches métavolcaniques, va de mafique à felsique. Le reste des roches métavolcaniques, c'est-à-dire 20 %, sont constituées de basaltes tholéiitiques et de komatiites basaltiques. Les basaltes alcalins sont essentiellement pyroclastiques; les constituants sont fréquemment amygdaloïdes et, de façon caractéristique, contiennent des phénocristaux idiomorphes de pyroxènes calciques monocliniques (cristaux maintenant largement pseudomorphosés par de l'amphibole). Les basaltes tholéiitiques se présentent invariablement sous forme coussinée ou de coulées massives, sont peu ou pas vacuolaire, non porphyrique et fréquemment variolitique.

La géochimie appuie le caractère distinctif de ces caractéristiques texturales. Les basaltes alcalins (moins de 53 % de SiO_2) contiennent une proportion élevée de K_2O (supérieure à 1 %) et une distribution des terres rares (TR) (normalisation par chondrite) qui montre un enrichissement en TR légères (TRL) ((Ce/Yb)N >5). Par contre, les basaltes tholéiitiques sont pauvres en K_2O (moins de 0,3 %) et présentent un profil TR (normalisation par chondrite) plat à légèrement penché en TRL ((Ce/Yb)N >1,5). Les basaltes calc-alcalins se situent entre ces extrêmes.

Des roches métesédimentaires apparaissent sous forme de conglomérats mineurs provenant du remaniement local de roches pyroclastiques, d'argilites et de siltstones, avec plusieurs horizons proéminants de grauwackes.

Les roches intrusives sont constituées de filons-couches synvolcaniques mafiques à felsiques; d'une suite de roches intrusives alcalines syntectonique à post-tectonique, comprenant des dykes de lamprophyre et un pluton de syénite, et enfin de deux plutons de granodiorite tardifs.

Les conditions métamorphiques maximales ont atteint le facies à amphibolite sur les deux tiers sud-ouest de la zone cartographiée et un facies à schistes verts sur le reste.

Les roches supracrustales ont été altérées de façon variable. Deux zones d'altération à hornblende-grenat sont orientées nord-est dans la région cartographiée, à l'intérieur d'assemblages à amphibolite. On peut suivre cette altération dans les roches à plus faible degré de métamorphisme qui sont fortement carbonatisées.

Malgré l'absence de production minière connue dans le passé ou à l'heure actuelle, la région cartographiée possède plusieurs caractéristiques qui la rendent intéressante pour l'exploration. Les roches qui offrent le meilleur potentiel pour

la recherche des métaux non-ferreux sont les roches métavolcaniques proximales intermédiaires à felsiques qui contiennent des phénocrystaux de quartz, surtout à l'ouest de Outer Bay où des fragments sulfures sont associées à ces roches métavolcaniques.

La recherche de l'or devrait être dirigée d'abord vers les zones de cisaillement à l'intérieur des unités métavolcaniques mafiques, surtout dans la région d'altération extensive à hornblende ± grenat et à carbonates.

La limite des facies à amphibolite et à schistes verts traverse les deux grandes zones d'altération à hornblende-grenat ou à carbonates pratiquement à angle droit; celle-ci devrait servir à orienter l'exploration initiale pour les métaux précieux. Un certain nombre d'échantillons prélevés dans les veines de quartz-carbonates-sulfures dans les zones de cisaillement au sein des formations métavolcaniques mafiques ont une teneur d'or supérieure à 0,1 ppm, avec une teneur maximale obtenue de 52,3 ppm.

Precambrian geology, Monument Bay area, Lake of the Woods, by M.G. Morrice, Ontario Geological Survey, Report 265, 69p. ISBN 0-7729-5663-4.

Introduction

LOCATION

Field investigations in 1987 represent the second year of a geological mapping project in the southwestern part of Lake of the Woods, initiated to complete the 1 inch to 1/4 mile (1:15 840) geological map base of the Lake of the Woods greenstone belt. An area of about 150 km² was mapped at a scale of 1:15 840. This area is bounded by latitudes 49°30′N and 49°22′N and longitudes 94°56′W and 94°47.7′W (Figure 1). The towns of Kenora, Ontario and Angle Inlet, Minnesota are located 50 km northeast and 20 km southwest, respectively, of the centre of the map area.

ACCESS

The map area is accessible by boat from either Kenora or Angle Inlet. The northwestern portion of the map area is reached by canoe from Mason and Reid lakes.

Except for areas underlain by granitic rocks, exposure of bedrock is generally poor due to a ubiquitous, though uneven, veneer of sandy till. However, exposures along the shore of Lake of the Woods are excellent. During the 1987 field season, the water level on Lake of the Woods was about 1 m below normal levels. This resulted in the exposure of many normally inundated outcrops.

PHYSIOGRAPHY

Elevations in the map area, as taken from 1:50 000 scale topographic maps published by the Surveys and Mapping Branch, Department of Energy, Mines and Resources (NTS 52 E/7, Falcon Island) range from 373 m above sea level, southeast of Reid Lake, to 323 m above sea level, the elevation of the mean water level on Lake of the Woods. Relief is generally less than 15 m but locally, as at Reid Lake, is as much as 50 m.

Most outcroppings form isolated hills which rise 5 to 20 m above intervening, flat, Pleistocene and Recent plain deposits while shoreline outcroppings are generally low and flat. Steep cliffs characterize shoreline exposures in Laser Bay, the S-shaped bay north of Cochrane Island, on the north side of Monument Bay.

Bedrock composition and structure have only a slight influence on topography, notably in linear ridges and valleys, and elongate islands and chains of islands.

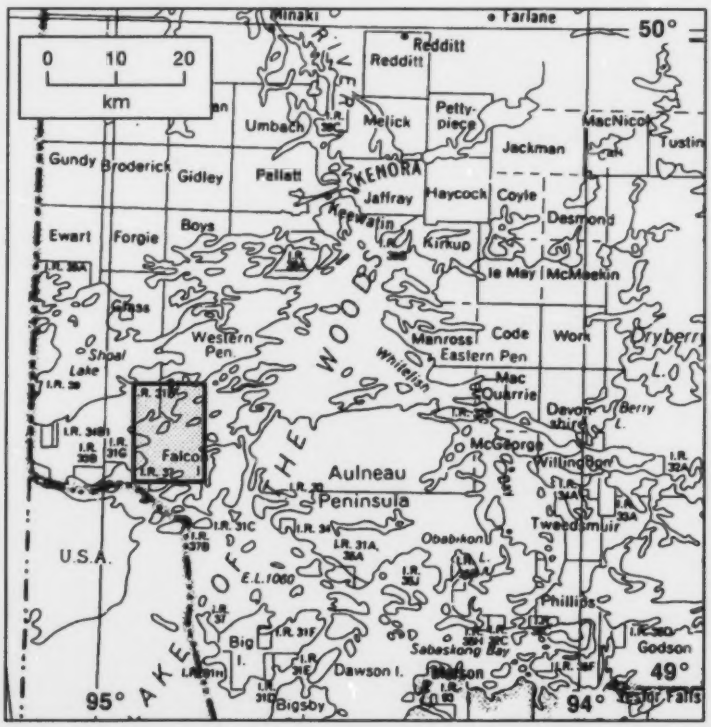

Figure 1. *Key map showing location of the Monument Bay Area. Scale 1:1 013 760 or 1 inch equals 16 miles.*

In general, drainage is poorly developed in the map area. Mason Lake and Reid Lake drain south into Lake of the Woods.

FIELD METHODS

Mapping was carried out by examining outcroppings along the shore of Lake of the Woods, and by pace and compass traverses inland. Traverses were run between outcroppings located on aerial photographs. No large exposures, and only a few small, were missed.

Geological data were plotted in the field on acetate sheets overlaid on 1:15 840 scale aerial photographs. The data were subsequently transferred to cronaflex base maps, scale-corrected to 1:15 840, which had been prepared from 1:20 000 OBM base maps by the Cartography Section, Ontario Ministry of Natural Resources.

PREVIOUS GEOLOGICAL WORK

The first recorded geological descriptions of the Lake of the Woods greenstone belt were the result of a reconnaissance survey made in 1883, 1884 and 1885, by Lawson (1885) who examined outcrops in the eastern part of the map area. During the period from 1893 to 1910, numerous gold deposits were discovered, and subsequently exploited, in the northern part of Shoal Lake, north of the present map area. In 1929, Greer (1931) examined outcrops in the north part of the map area as part of a geological mapping program on Shoal Lake.

The Monument Bay map area adjoins the Western Peninsula map sheet (Davies 1983) to the north and the Northwest Angle Inlet sheet to the west (Morrice and MacMaster 1987).

MINING AND EXPLORATION HISTORY

Despite several periods of intensive exploration and mining activity in the northern part of Lake of the Woods greenstone belt, there is no record of mining activity and very little in the way of recorded information concerning exploration activity in the Monument Bay map area. The activity in the northern part of the belt focussed on gold in the 1880s through the early 1900s, in the 1930s through the early 1940s, and from the mid-1970s to the present. Base metal exploration activity peaked in the 1960s and into the 1970s.

There are no confirmed records of historic gold exploration within the present map area.

Base metal (zinc, copper) exploration was carried out during the early to mid-1970s in the central and northern part of the map area, by Hudson Bay Exploration and Development Company Limited and Phelps Dodge Corporation of Canada Limited.

ACKNOWLEDGMENTS

Capable assistance in the field was provided by G.A. MacMaster, K. Cook, H. Charbonneau and H. Douglas. MacMaster, as senior assistant, was responsible for approximately half of the mapping.

Charbonneau undertook a Bachelor of Science thesis, at the University of Western Ontario, on the hydrothermal alteration of alkalic, pillowed, intermediate metavolcanics of the Johnston Passage formation. Her contribution to the understanding of this amphibolite facies alteration is gratefully acknowledged.

Thanks are also extended to S. Buck who helped with the structural geology of the Monument Bay deformation zone.

General Geology

INTRODUCTION

The Monument Bay area is underlain by an east- to northeast-trending sequence of Archean metavolcanic and metasedimentary rocks (Figure 2). These supracrustal rocks have been intruded by Archean syn- to late-tectonic granitic and syenitic plutons, and north-northwest-trending Proterozoic diabase dikes (Table 1).

Supracrustal rocks underlie approximately 95 percent of the Monument Bay area; igneous plutonic rocks underlie the remaining 5 percent. The supracrustal rocks are mainly metavolcanic and range in composition from ultramafic to felsic. Metasediments are about five percent of the supracrustal rocks.

On the basis of field observations and geochemical data from the adjoining Northwest Angle Inlet map area, two distinct geochemical packages are recognized in the Monument Bay and Northwest Angle Inlet map areas. An alkalic (shoshonitic) to calc-alkalic association comprises about 80 percent of the metavolcanics, with compositions ranging from mafic to felsic. The remaining 20 percent of metavolcanics are an intimate mixture of tholeiitic basalts and a subset of lesser basaltic komatiites; these together constitute the tholeiite association. These two associations are readily distinguishable in the field.

This subdivision into alkalic (shoshonitic), calc-alkalic and tholeiitic suites follows that of MacKenzie and Chappell (1972) and Gill and Whelan (1989). A plot of K_2O versus SiO_2 (Figure 3) serves to distinguish a shoshonitic suite from calc-alkalic suites, which, however appear to be compositionally gradational. The tholeiitic suite can be distinguished from calc-alkalic and alkalic suites on this diagram, or with more conventional Jensen cation or AFM diagrams (Figure 4, Figure 5).

Volcanic rocks of the shoshonitic association are virtually restricted, in the Cenozoic, to convergent plate boundaries. Shoshonic volcanic rocks are characterized by high K_2O content, when compared to tholeiitic and calc-alkalic volcanic rocks, and by high K_2O/Na_2O and low concentrations of high-field-strength elements (e.g., TiO_2, Zr), when compared to alkalic volcanic rocks erupted at within-plate tectonic settings (Joplin 1968).

Alkalic basaltic rocks are predominantly clastic; individual clasts commonly are highly amygdaloidal

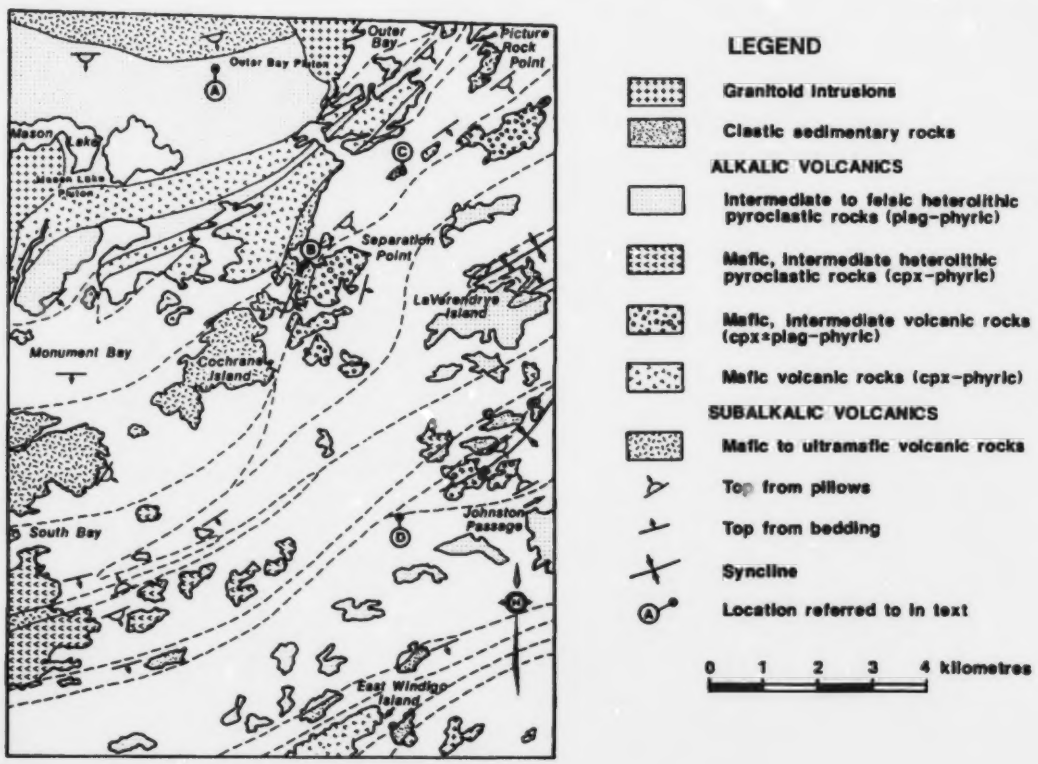

Figure 2. *Generalized geology of the Monument Bay Area.*

TABLE 1. TABLE OF LITHOLOGIC UNITS FOR THE MONUMENT BAY AREA.

PHANEROZOIC

CENOZOIC

QUATERNARY

Pleistocene and Recent

Glacial, glacial-fluvial, swamp, lacustrine and fluvial deposits

Unconformity

PRECAMBRIAN

PROTEROZOIC

MAFIC INTRUSIVE ROCKS

Diabase, quartz diabase

Intrusive Contact

ARCHEAN

INTERMEDIATE TO FELSIC INTRUSIVE ROCKS

Aplite, pegmatite, biotite-hornblende granite, hornblende-biotite granodiorite, hornblende diorite,

Intrusive Contact

ALKALIC INTRUSIVE ROCKS

Syenite, lamprophyre, biotite lamprophyre, hornblendite, monzodiorite, pebble dike

Intrusive Contact

METAMORPHOSED INTERMEDIATE TO FELSIC INTRUSIVE ROCKS

Quartz-feldspar porphyry, feldspar porphyry, felsite.

Intrusive Contact

METAMORPHOSED MAFIC INTRUSIVE ROCKS

Gabbro, melanogabbro, leucogabbro, quartz gabbro, fine grained gabbro, mafic feldspar porphyry.

Intrusive Contact

METAMORPHOSED ULTRAMAFIC INTRUSIVE ROCKS

Pyroxenite, hornblendite.

Intrusive Contact

METAVOLCANIC AND METASEDIMENTARY ROCKS

METASEDIMENTS

CLASTIC AND CHEMICAL METASEDIMENTS

Feldspathic wacke, quartz-feldspar wacke, siltstone, arenite, argillite, conglomerate chert, ironstone, quartz-plagioclase-biotite schist

METAVOLCANICS

INTERMEDIATE TO FELSIC METAVOLCANIC ROCKS (Alkalic-Calc-alkalic)

Tuff, lapilli tuff, lapillistone, tuff breccia, massive flow, pillowed flow, flow breccia

INTERMEDIATE VOLCANICS (Alkalic-Calc-alkalic)

Massive flow, pillowed flow, flow breccia, tuff, lapilli tuff, lapillistone, tuff breccia,

MAFIC METAVOLCANICS (Alkalic-Calc-alkalic)

Clinopyroxene-phyric massive flows, pillowed flows, pillow breccia, tuff, lapilli tuff, lapillistone, tuff breccias.

ULTRAMAFIC TO MAFIC METAVOLCANICS (Subalkalic)

Fine-grained massive flows, coarse-grained massive flows (may in part be intrusive), pillowed flows, pillow breccia, tuff, lapilli tuff, tuff breccia.

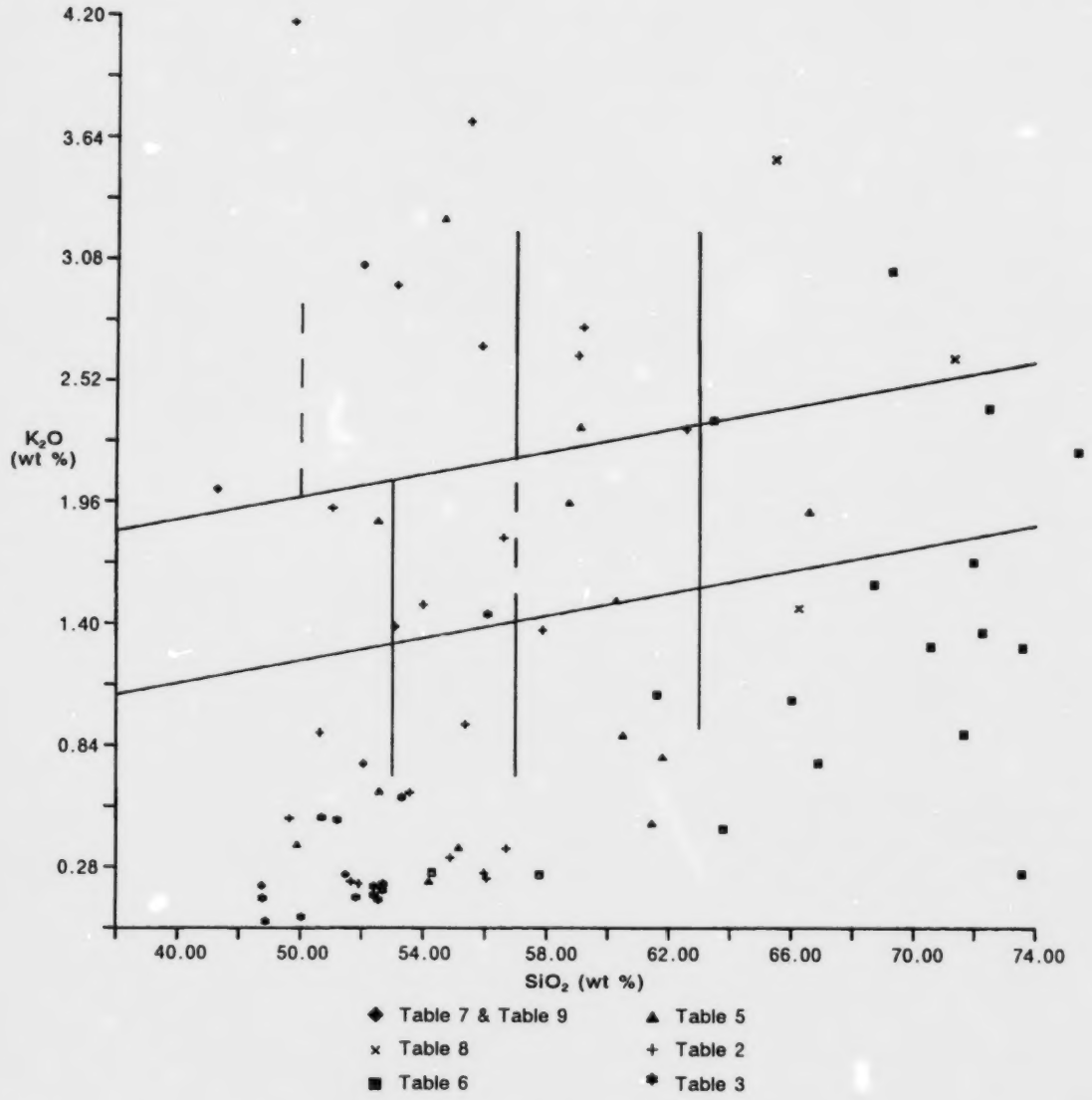

Figure 3. *K_2O versus SiO_2 diagram, Monument Bay area.*

and characteristically contain euhedral, calcic clinopyroxene phenocrysts (now largely pseudomorphed by amphibole). Tholeiitic basalts are invariably pillowed or massive flows, non- to weakly vesicular, aphyric, and commonly variolitic.

These subdivisions on distinct megascopic features are supported by geochemistry. Alkalic basalts (SiO_2 less than 53 percent) have elevated K_2O contents (K_2O greater than 1 percent) and REE patterns showing enrichment in light REE ($(Ce/Yb)_N > 5$). On the other hand, tholeiitic basalts are low in K_2O (K_2O less than 0.3 percent) and have REE patterns which are flat to slightly depleted in LREEs ($(Ce/Yb)_N < 1.5$). Calc-alkalic basalts are intermediate in composition between these extremes. Alkalic, calc-alkalic and tholeiitic metavolcanics are interlayered and appear to form a conformable sequence.

The supracrustal rocks of the Monument Bay map area have been subdivided into 15 formations on the basis of distinct field and textural characteristics (Figure 6) (Table 2). This lithostratigraphic subdivision is tentative, pending the completion of detailed mapping of the Lake of the Woods greenstone belt. With the exception of the tholeiitic Cochrane Island and Partridge Lake formations, and the metasedimentary Long Island, Royal Island, Betty Island and Burnt Island formations, these units are

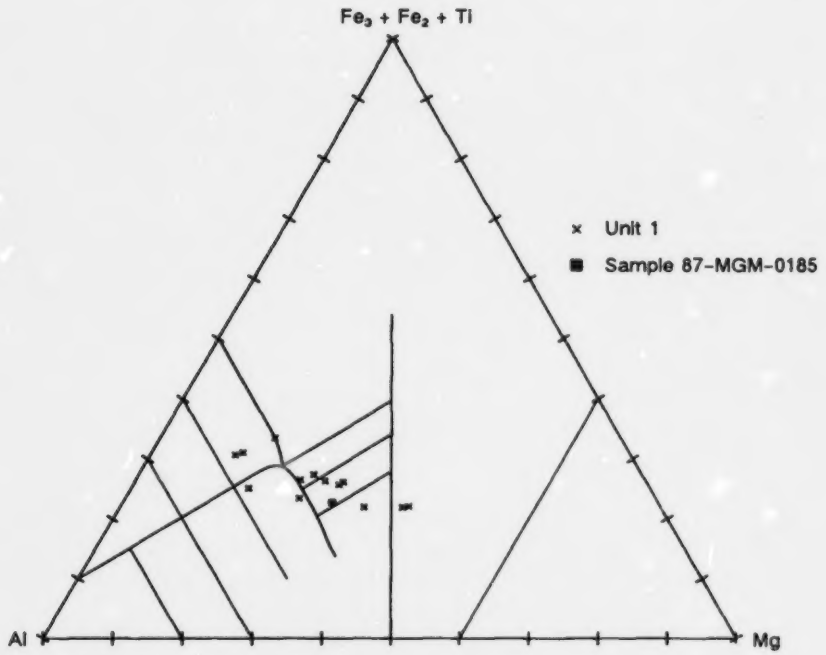

Figure 4. *Jensen cation diagram-tholeiitic metavolcanics, Monumen' Bay area.*

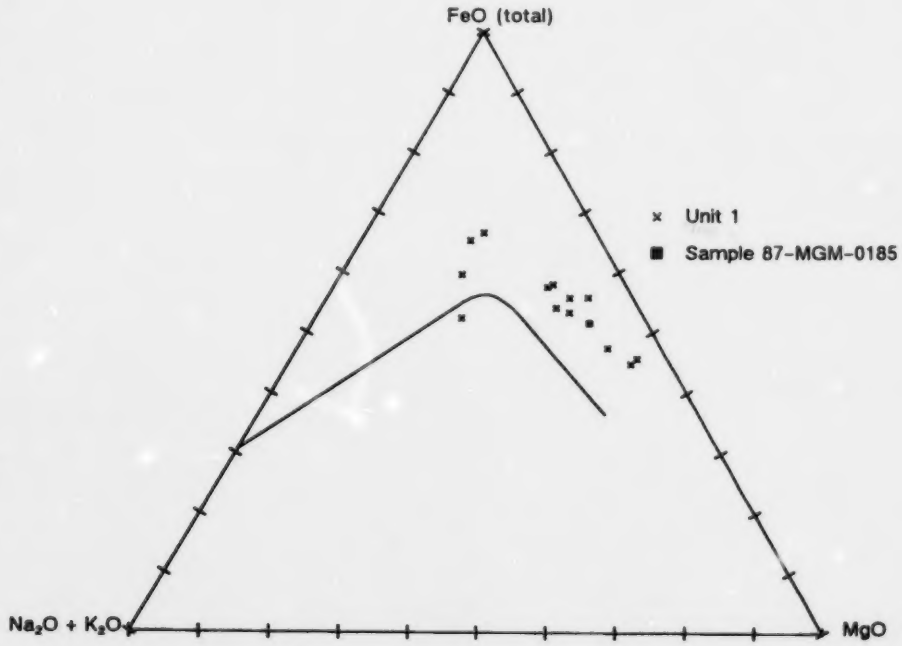

Figure 5. *AFM diagram-tholeiitic metavolcanics, Monument Bay area.*

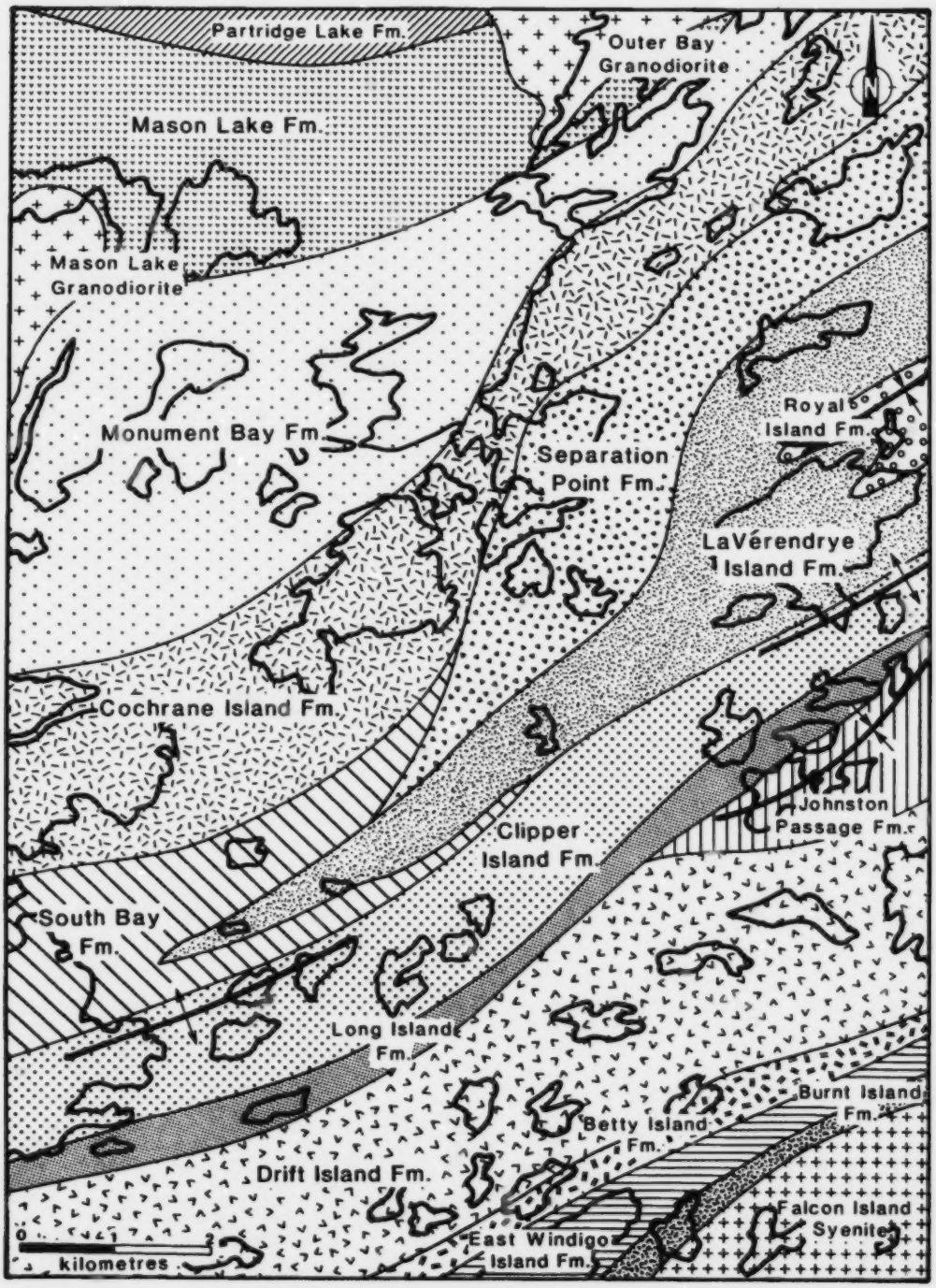

Figure 6. *Map showing the distribution of informal formations, Monument Bay area.*

TABLE 2. TABLE OF FORMATIONS FOR THE MONUMENT BAY AREA.

Johnston Passage formation (0 to 500 m)[1]
intermediate pillowed flows, pillow breccia:
plagioclase-phyric, vesicular

Long Island formation (450 m)
thick-bedded wacke, minor iron formation

Drift Island formation (1500 m)
intermediate-felsic pyroclastics:
plagioclase-phyric

Betty Island formation (400 m)
wacke, iron formation

East Windigo Island formation (600 m)
mafic pyroclastics:
clinopyroxene-phyric

Burnt Island formation (200 m)
wacke

Clipper Island formation (500 to 1000 m)
mafic pillowed flows; mafic, intermediate pyroclastics:
clinopyroxene- and plagioclase-phyric

Royal Island formation (200 m)
thick bedded wacke

La Vérendrye Island formation (0 to 2000 m)
intermediate-felsic pyroclastics:
aphyric

South Bay formation (0-1900 m)
mafic, intermediate pyroclastics, mafic flows:
clinopyroxene- and plagioclase-phyric

Separation Point formation (0 to 1700 m)
mafic pyroclastics, flows:
clinopyroxene- and plagioclase-phyric, vesicular

Cochrane Island formation (600 to 2000 m)
ultramafic, mafic pillowed and massive flows:
aphyric, non-vesicular, variolitic

Monument Bay formation (600 to 2500 m)
mafic pyroclastics, massive and pillowed flows, intermediate to felsic pyroclastics:
clinopyroxene-phyric, vesicular

Mason Lake formation (1500 to 2000 m)
intermediate-felsic pyroclastics:
plagioclase-, quartz-phyric

Partridge Lake formation (>500 m)
mafic flows, pyroclastics:
plagioclase-phyric

[1]*Approximate thickness of formation, in metres.*

composed mainly, or entirely, of alkalic and calc-alkalic metavolcanics.

Tholeiitic, mafic to ultramafic metavolcanics, mainly pillowed and massive basalts and basaltic komatiite flows, are the main rock types of the Partridge Lake and Cochrane Island formations but also occur as mappable units within the South Bay, Separation Point, Clipper Island and Drift Island formations. Alkalic and lesser calc-alkalic, mafic metavolcanics constitute the Monument Bay, Separation Point, South Bay and Clipper Island formations. Calc-alkalic and lesser alkalic, intermediate metavolcanics occur within the Johnston Passage and Separation Point formations. The Mason Lake, La Vérendrye Island and Drift Island formations are underlain mainly by calc-alkalic, intermediate to felsic metavolcanics.

The volcanic sequence in the Monument Bay map area is estimated to be 10 km thick. The stratigraphic base is the mafic metavolcanics of the Partridge Lake formation. The top of the stratigraphic succession is placed at the uppermost intermediate flows in the Johnston Passage formation. The general compositional evolution with increasing stratigraphic elevation is from mafic to felsic. Several thin horizons of epiclastic metasediments occur interbedded with metavolcanics near the top of the succession. Repetition of units by folding and/or faulting is suspected in the southern part of the map area (i.e., near the top of the sequence), where facing directions are poorly preserved.

Prior to metamorphism and deformation, the volcano-sedimentary sequence was intruded by many synvolcanic sills. These sills range in composition from ultramafic to felsic, and constitute less than five percent of the stratigraphic sequence. Individual sills are generally less than 100 m thick.

A suite of compositionally and texturally diverse lamprophyre dikes were emplaced into the volcano-sedimentary sequence over a protracted period of time, from syn- to posttectonic. These dikes range in width from less than 5 cm to about 100 m, and in composition from monzodiorite to biotite hornblendite. These intrusions are volumetrically minor (less than one percent) but are ubiquitous throughout the map area.

A syenite border phase of the Falcon Island igneous complex is exposed in the southeastern part of the map area. Lamprophyre dikes intrude ultramafic phases of the Falcon Island Complex immediately southeast of the map area, indicating that the complex either predates, or is synchronous with, lamprophyre dike emplacement.

Syn- to late-tectonic felsic igneous activity resulted in the emplacement of the Mason Lake and Outer Bay hornblende-biotite granodiorite plutons.

The volcano-sedimentary sequence was metamorphosed under greenschist and amphibolite facies conditions. The amphibolite-greenschist isograd

trends approximately east across the northern part of the map area. The amphibolite facies metamorphism defines a broad contact aureole related to the Sabaskong Batholith, which is located south of the Monument Bay map area (Blackburn 1981).

The last igneous event was the emplacement of north-northwest-trending Proterozoic diabase dikes.

METAVOLCANIC AND METASEDIMENTARY ROCKS

THOLEIITIC METAVOLCANIC ROCKS

Mafic to Ultramafic Metavolcanic Rocks

Tholeiitic mafic, and ultramafic metavolcanics constitute two formations (Partridge Lake and Cochrane Island), and occur as mappable units in two formations (South Bay and Clipper Island), and as thin interbedded flows in two formations (Separation Point and Drift Island) (*see* Figure 6). They represent tholeiitic basalts and basaltic komatiite flows metamorphosed under amphibolite and greenschist facies conditions.

On weathered surfaces, ultramafic metavolcanics weather light to medium green while mafic metavolcanics weather black to dark green. The colour of both becomes lighter with decreasing metamorphic grade. On fresh surfaces, ultramafic metavolcanics are medium to dark green and mafic metavolcanics are black to dark green. Both the mafic and ultramafic metavolcanics range from well foliated to massive.

Tholeiitic mafic, and ultramafic metavolcanics are non-vesicular to sparsely vesicular, mainly aphyric, flows. Plagioclase-phyric flows are found in the Clipper Island formation, with phenocrysts ranging in size from 1 to 5 mm and in abundance up to 25 percent.

Minor, but conspicuous, equant plagioclase phenocrysts, up to 1 cm in diameter, are also present in mafic metavolcanics in the Partridge Lake, Cochrane Island and Separation Point formations. These plagioclase megacryst, or "leopard rock", flows resemble similarly conspicuous flows in the Lower Mafic group elsewhere on Lake of the Woods (e.g., Ayer *et al.* 1985). The presence of leopard rock within the Upper Diverse group in the Monument Bay area demonstrates that these rocks are not restricted to the Lower Mafic group in the Lake of the Woods area (cf. Wilson *et al.* 1974; Ayer and Sweeny 1986; Ayer and Gil 1986; Ayer *et al.* 1985).

Individual flows, 5 to 25 m thick, occur as simple or compound flow units. Most simple flows are pillowed and either mafic or ultramafic in composition (Photo 1). Simple massive flows are rare and tend to be mafic in composition. Compound flows are common and are characterized by massive mafic bases overlain by pillowed ultramafic tops. The mafic to ultramafic transition is gradational over 1 to 2 m near the top of the massive portion of the flow.

The massive mafic bases are medium grained to coarse grained; many contain conspicuous, 0.5 to 10 cm long dendritic pyroxene crystals (pseudomorphed by amphibole) indicating crystallization due to supercooling. Simple pillowed and compound flows are invariably variolitic with light coloured varioles, 2 to 20 mm in diameter, concentrated near the tops of massive flows and near selvages in pillowed flows. Individual pillows are 0.5 to 1.0 m long, have 0.5 to 1.0 cm wide selvages and may be associated with pillow breccia.

Ultramafic metavolcanics are composed of 65 to 75 percent pale green tremolite-actinolite and (20 to 30 percent) subordinate plagioclase. Ultramafic metavolcanics metamorphosed under greenschist facies conditions contain 20 to 40 percent chlorite, 30 to 50 percent tremolite-actinolite and 20 to 30 percent subordinate plagioclase. Opaque minerals, present to less than two percent, are finely disseminated.

Mafic metavolcanics contain 30 to 50 percent plagioclase and 50 to 60 percent amphibole; the latter is deep blue-green hornblende in amphibolite facies rocks and pale green actinolite in greenschist facies rocks. Minor mineral phases in both mafic and ultramafic metavolcanics include epidote, quartz, calcite and opaque minerals.

The polarity of the compound flows, as defined by their mafic bases and ultramafic tops, is opposite to what would be expected if crystal-liquid processes, involving settling of high temperature iron-magnesium mineral phases, were operative. The lack of phenocrysts in these flows suggests that this polarity is due to liquid-liquid processes, possibly analogous to those associated with the mixed komatiitic lavas of Munro Township (Arndt and Nesbitt 1984). The polarity of these flows can be explained by the injection of an ultramafic liquid into the bottom of a magma chamber dominated by mafic liquids, thereby triggering an eruption with the mafic liquids erupting first and the ultramafic liquids following.

The tholeiitic basalts and basaltic komatiites of the Cochrane Island formation are intruded by synvolcanic, mafic and intermediate to felsic sills.

ALKALIC (SHOSHONITIC) TO CALC-ALKALIC METAVOLCANIC ROCKS

Mafic Metavolcanic Rocks

Alkalic mafic metavolcanics are the main rocks in the Monument Bay, Separation Point, South Bay and East Windigo Island formations, and constitute a significant proportion of the Clipper Island formation (*see* Figure 6). Weathered surfaces grade from medium grey to dark grey for amphibolite facies grade rocks, to medium green to dark green for greenschist facies grade rocks; fresh surfaces are

Photo 1. *Pillowed (bottom of photo) and massive (top of photo) basaltic komatiites, South Bay formation, South Bay. Rubbly, carbonatized flow contact can be seen immediately below hammer.*

dark grey to dark green. Alkalic mafic metavolcanics which have been metamorphosed to amphibolite grade are biotite-bearing, which results in a characteristic sheen to outcrop surfaces in sunlight. Alkalic mafic metavolcanics range from massive to well foliated.

Alkalic mafic metavolcanics occur as pyroclastic rocks in the Separation Point, South Bay, Clipper Island and East Windigo Island formations. The Monument Bay formation is composed of approximately equal proportions of flows and pyroclastics. The flows occur mainly in the north, at the base of the formation, while pyroclastics are abundant in the south, the top of the formation. Alkalic mafic metavolcanics are interbedded with alkalic intermediate to felsic pyroclastics in the Monument Bay and Clipper Island formations, with calc-alkalic intermediate flows and pyroclastics in the Separation Point formation, and with tholeiitic mafic flows in the South Bay formation.

The most striking textural feature of these rocks is the presence of euhedral, equant, 2 to 10 mm diameter, calcic clinopyroxene phenocrysts, now largely pseudomorphed by amphibole and biotite (Photo 2), which range in abundance up to 40 percent. Calcic clinopyroxene phenocrysts have been documented in various stages of degradation in the Monument Bay area, and the Northwest Angle Inlet area to the west (Morrice and MacMaster 1987). Fresh, oscillatory and sector-zoned clinopyroxene phenocrysts occur in massive flows in the Mackay Island area of Shoal Lake (Morrice and MacMaster 1987). With increasing grade of metamorphism, these clinopyroxene phenocrysts are pseudomorphed by actinolite and hornblende. With increasing deformation, the clinopyroxene phenocrysts are flattened and altered to biotite. Where deformation is particularly severe, as in the Monument Bay deformation zone, all that remains of the original clinopyroxene phenocrysts are thin biotite wisps or discs (0.2 to 0.5 mm by 5 to 10 mm), flattened in the plane of foliation (Photo 3).

Many of the mafic alkalic metavolcanics are also plagioclase-phyric, with phenocrysts ranging in abundance up to about 20 percent. The morphology of these phenocrysts is very distinctive, with very slender, tabular crystals having length to width ratios of about 5 to 1 (Photo 4). They range in length from about 3 mm to 2.5 cm and all are variably saussuritized. Flows and clasts within pyroclastic deposits are commonly amygdaloidal, with up to 50 percent calcite- and/or quartz-filled amygdules which are generally 0.5 to 2 mm, but which range up to 10 cm.

North of Monument Bay, at the base of the Monument Bay formation, a laterally persistent horizon of clinopyroxene-phyric, amygdaloidal, pillowed and massive basalt has been traced for 12 km along strike; it decreases in thickness from 1 km in the Northwest Angle Inlet area (Morrice and MacMaster 1987) to 30 m near Picture Rock Point. This unit contains 10 to 25 percent clinopyroxene phenocrysts, mostly altered to biotite, and 5 to 40 percent calcite-filled amygdules. Pillows are large, up to 3 m in diameter, and selvages are thick, 3 to 5 cm. A similar unit occurs 1.5 km to the south of this horizon.

The alkalic mafic units which underlie the south half of the Monument Bay, Separation Point, and East Windigo Island formations are composed mainly of tuff breccia, lapilli tuff and tuff, with lesser

Photo 2. *Clinopyroxene phenocrysts (pseudomorphed by amphibole) in alkalic mafic pyroclastics, Monument Bay formation, Monument Bay.*

Photo 3. *Flattened and "biotitized" clinopyroxene phenocrysts, Monument Bay formation, Monument Bay. Field of view is 15 cm.*

pillowed and massive flows. Pillows are similar to those which occur in the pillowed unit at the base of the Monument Bay formation. Massive flows are blocky and characterized by clinopyroxene-phyric autoclastic breccias (Photo 5). Bedding is well developed in the pyroclastics and ranges in thickness from less than 1 cm in the tuffs to greater than 2 m in the tuff breccias (Photo 6). Coarse pyroclastics range from matrix supported to clast supported. All three formations are characterized by monolithic pyroclastics containing abundant scoria clasts. Bomb sags, and coarse and diffusely bedded tuffs, suggest proximal deposition in a shallow water or subaerial environment (Fisher and Schmincke 1984; Williams and McBirney 1979) (Photo 7). Cross-bedding and scour features may have formed from pyroclastic surges associated with phreatomagmatic volcanic activity (Photo 8) (e.g., Fisher and Schmincke 1984). As little or no reworking is evident, these deposits are interpreted to be primary pyroclastics deposited in a series of locally emergent cinder cones.

Alkalic mafic metavolcanics in the South Bay area include a conspicuous component of predominantly heterolithic pyroclastics which are interbedded with subordinate, tholeiitic mafic and calc-

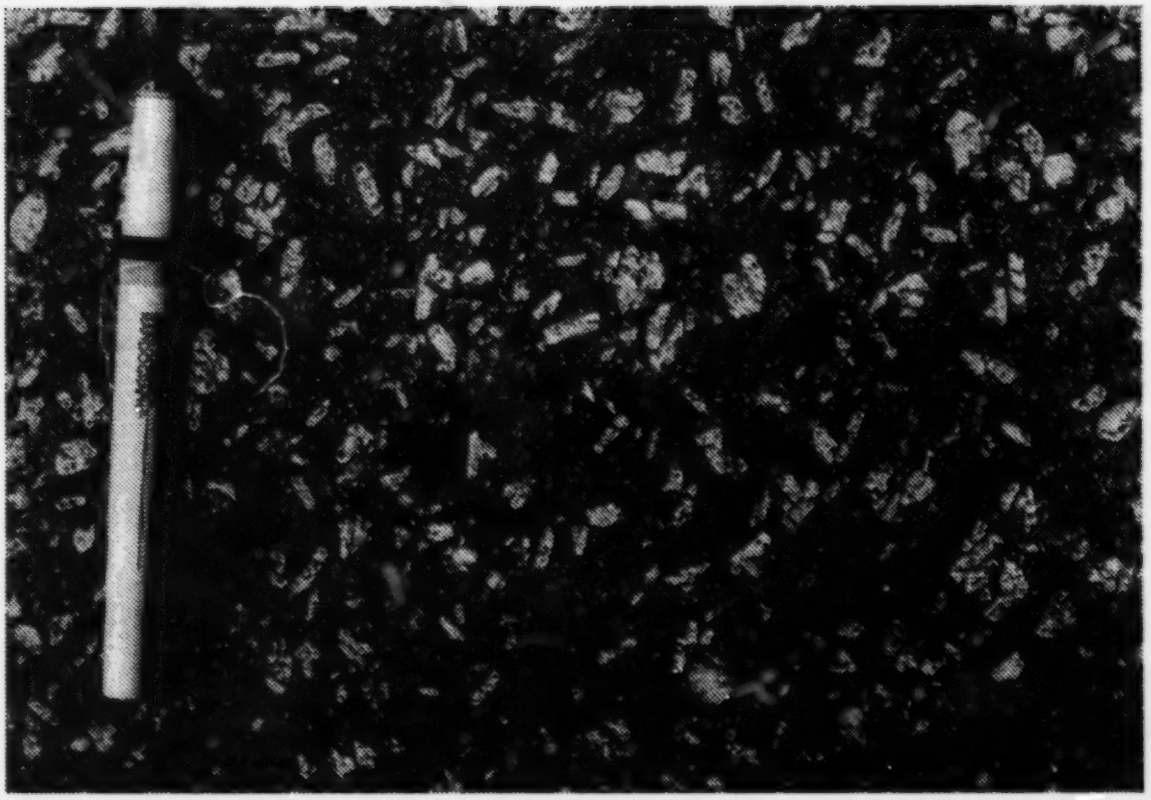

Photo 4. *Tabular plagioclase phenocrysts in mafic, plagioclase and clinopyroxene porphyry subvolcanic dike, Separation Point Formation, northeast of Separation Point.*

alkalic intermediate flows. The heterolithic pyroclastics are well bedded debris flows up to several metres thick, consisting of varying proportions of alkalic and calc-alkalic, mafic and intermediate clasts. Many of the intermediate clasts are aphyric or only plagioclase-phyric, and of calc-alkalic affinity. The alkalic component of these rocks is present as clinopyroxene-phyric mafic and intermediate clasts and as a significant, but variable, clinopyroxene-bearing matrix component.

All clinopyroxene crystals, except for phenocrysts from a porphyritic sill in the Mason Lake formation, have been replaced by metamorphic hydration products. At amphibolite facies grade metamorphism these are hornblende and biotite, while at greenschist facies grade, clinopyroxene is pseudomorphed by actinolite, biotite and carbonate. Additional groundmass phases include epidote and opaque minerals. Carbonate is much more abundant in rocks of lower metamorphic grade.

The most diagnostic metamorphic mineral of the alkalic mafic metavolcanics of amphibolite facies grade is biotite, which occurs scattered through the matrix and as reaction rims on, or wholly replacing, pseudomorphed clinopyroxene phenocrysts. The presence of biotite is due to the reaction of unstable potassium-bearing groundmass phases, possibly sanidine, with ferromagnesian components in the rock (cf. Brooks *et al.* 1982); i.e., this "biotitization" is not due to potash metasomatism.

Intermediate Metavolcanic Rocks

Calc-alkalic, and lesser alkalic, intermediate metavolcanics occur as plagioclase-phyric flows and, to a lesser extent, pyroclastics in the Separation Point and Johnston Passage formations (*see* Figure 6). Weathered surfaces are light grey; fresh surfaces are light grey to medium grey. These intermediate metavolcanics are massive to well-foliated.

Alkalic to calc-alkalic intermediate metavolcanics are also found as aphyric and plagioclase-phyric clasts forming a minor component of heterolithic, mafic and intermediate to felsic pyroclastics in the Mason Lake, Monument Bay, South Bay, Separation Point, La Vérendrye Island and Drift Island formations.

Flow units are composed of pillows and pillow breccia with 10 to 25 percent, 2 to 5 mm long, plagioclase phenocrysts in a groundmass containing 10 to 25 percent calcite- and quartz-filled amygdules. The plagioclase phenocrysts have slender, tabular

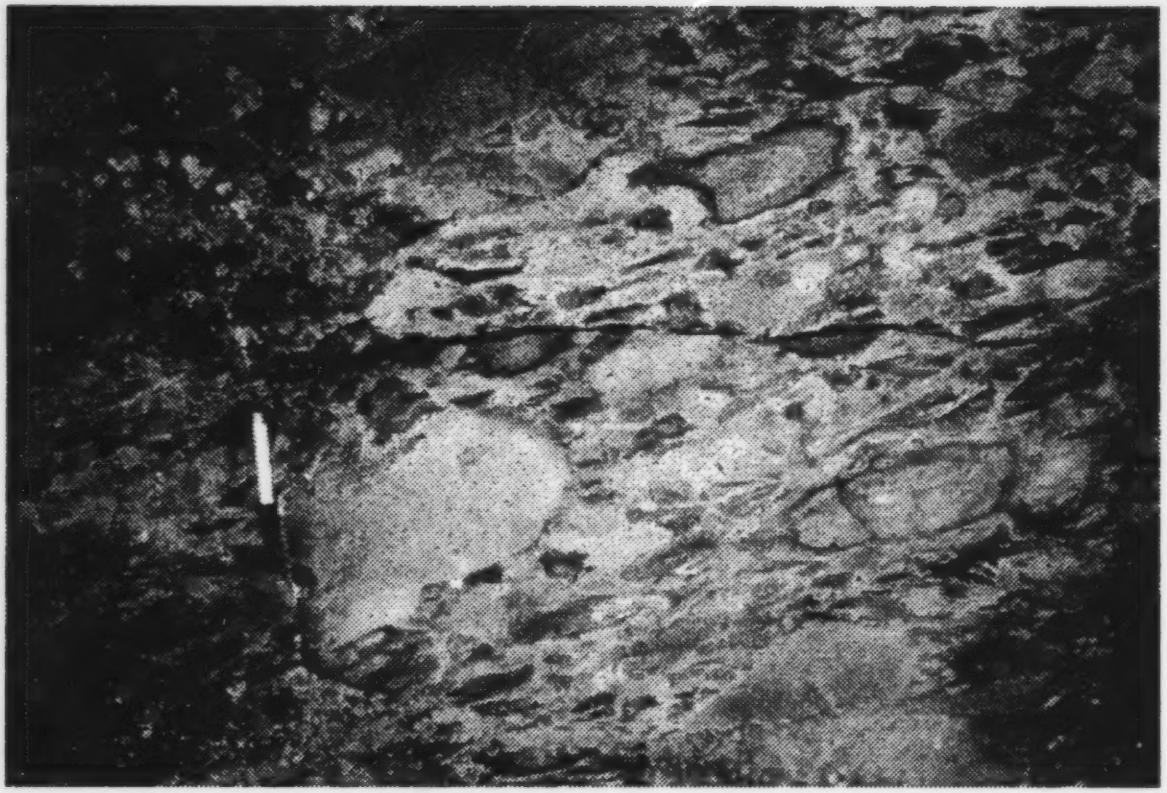

Photo 5. *Autoclastic clinopyroxene-phyric blocky flow, Monument Bay formation, Monument Bay.*

morphologies, similar to those described previously from alkalic mafic metavolcanics. Pillows are 50 to 100 cm by 25 to 50 cm and are characterized by 2 to 5 cm thick selvages. Pillow breccias are especially abundant in the Johnston Passage formation (Photo 9). Individual flows are 5 to 10 m thick and are interbedded with both coarse and fine pyroclastics.

Intermediate pyroclastics are poorly sorted, well-bedded, matrix-supported deposits with bedding thickness ranging from less than 20 cm to greater than 4 m. They are interpreted to be debris flows, on the basis of their poorly sorted, heterolithic nature.

Plagioclase phenocrysts are in varying stages of alteration to saussurite. The groundmass of individual clasts is characterized by a fine-grained mosaic of quartz and feldspar with 10 to 25 percent biotite and 5 to 15 percent hornblende. Accessory phases include epidote, carbonate and opaque minerals.

Intermediate clasts within pyroclastic deposits contain hornblende and/or biotite aggregates, 5 mm to 2 cm in size. As with the clinopyroxene phenocrysts, these inclusions were observed in various stages of degradation, from pseudomorphed clinopyroxene crystal aggregates to flattened biotite wisps. These are especially evident in clasts in the South Bay formation. Such inclusions are common in Cenozoic volcanic rocks where they have been interpreted to be accumulations of cumulate clinopyroxene crystals which were incorporated into the intermediate magma in the magma chamber (e.g., Arculus and Wills 1980). With increasing metamorphism and deformation, the clinopyroxenes are pseudomorphed by hornblende which is in turn replaced by biotite, as was documented for the clinopyroxene phenocrysts of the alkalic mafic metavolcanics.

Intermediate to Felsic Metavolcanic Rocks

Calc-alkalic, intermediate to felsic metavolcanics are the main compositions present in the Mason Lake, La Vérendrye Island, and Drift Island formations in the lower half of the Monument Bay formation (*see* Figure 6). In the Drift Island formation, heterolithic pyroclastics predominate and synvolcanic sills are abundant. Weathered and fresh surfaces are light grey to buff. Intermediate to felsic metavolcanics are massive to well foliated.

Intermediate to felsic metavolcanics consist predominantly of heterolithic tuff breccia, lapilli tuff and tuff; monolithic pyroclastics are less abundant in the Mason Lake and Drift Island formations. Plagioclase-phyric clasts with 1 to 3 mm, equant

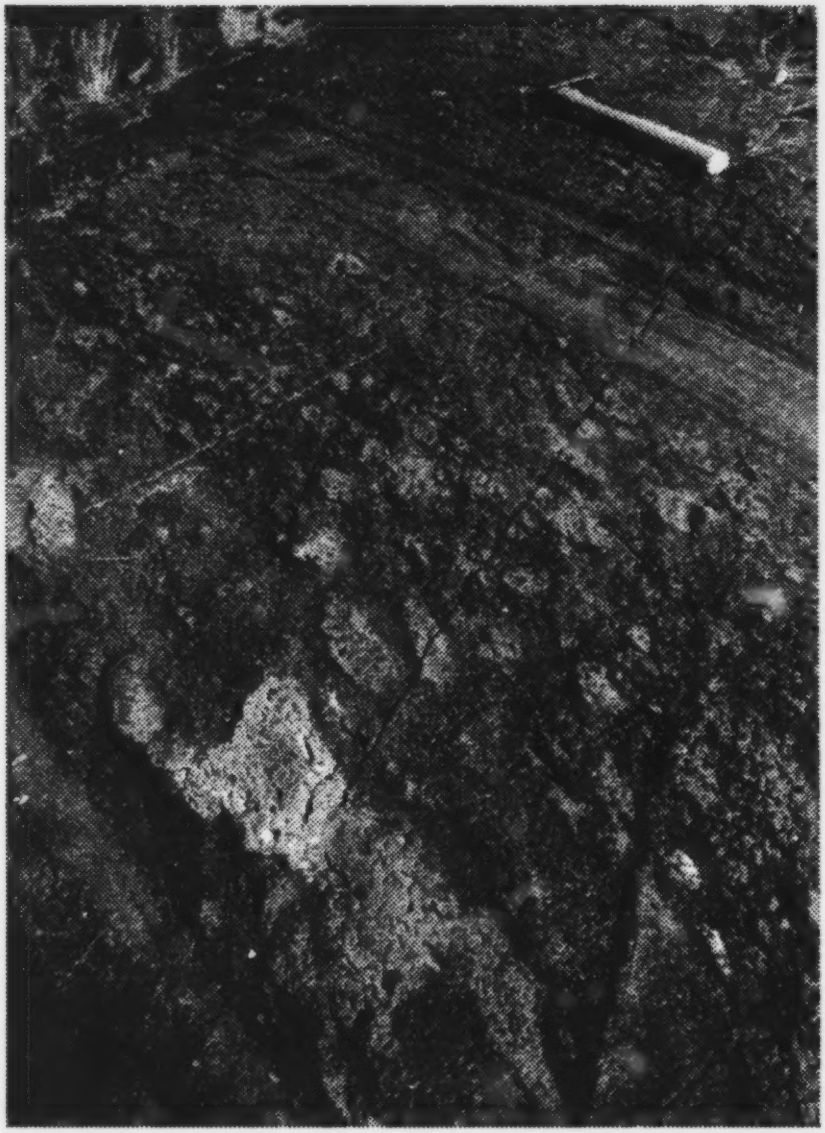

Photo 6. *Well-bedded clinopyroxene-phyric pyroclastics, Monument Bay formation, Monument Bay.*

phenocrysts are 5 to 30 percent of the intermediate to felsic pyroclastics in the Mason Lake, Monument Bay and Drift Island Formations. Aphyric clasts are less common. Felsic clasts within the equivalent rocks in the La Vérendrye Island formation are mainly aphyric.

Individual heterolithic pyroclastic deposits are poorly sorted, clast supported and thickly bedded. They are interpreted, on the basis of their poorly sorted and heterolithic nature, to have been deposited as debris flows. Local reworking of these debris flows is evident in the Monument Bay formation, where conglomerates with well-rounded cobbles of aphyric, intermediate to felsic volcanic rocks are interbedded with debris flows and feldspathic wackes. Quartz-plagioclase porphyry clasts occur in discrete, monolithic to heterolithic pyroclastics west of Outer Bay in the Mason Lake formation and west of Falcon Island in the Drift Island formation. In the Mason Lake formation these monolithic tuff breccias also contain minor, 5 to 10 mm diameter clasts composed wholly of pyrrhotite and pyrite. These pyroclastics grade laterally into heterolithic tuff breccias, suggesting lateral reworking of the brecciated carapace of a felsic dome. The sulphide clasts may

Photo 7. *Ballistically emplaced, spindle-shaped, clinopyroxene-phyric volcanic bomb (transport direction from top to bottom (east to west)) in clinopyroxene-phyric tuffs, Monument Bay formation, Monument Bay.*

have been incorporated from reworked exhalative massive sulphide deposits associated with the dome.

In the Drift Island formation, quartz-plagioclase porphyry clasts which occur in pyroclastic deposits have similar textures to massive quartz-plagioclase porphyry units which occur throughout this formation. This suggests a cogenetic link between these clasts and the massive porphyry units. However, it is not clear whether these massive porphyries are flows that have supplied detritus to felsic pyroclastics, or are simply synvolcanic sills.

Well-bedded, intermediate to felsic tuffs are minor but ubiquitous components of all intermediate to felsic formations. Bedding ranges in thickness from 1 mm to greater than 1 m.

Quartz phenocrysts are deeply embayed, indicating resorption by surrounding magma. Plagioclase phenocrysts are equant to lath-shaped and in varying stages of saussuritization; many display oscillatory zoning. The oscillatory zoning is typical of plagioclase phenocrysts formed in a volcanic environment, and indicates crystal growth in shallow magma chambers (e.g., Gill 1981). The groundmass of porphyritic clasts is composed of a fine-grained quartz-feldspar mosaic with minor biotite, sericite, carbonate and opaque minerals. The matrix to the clasts contains 5 to 15 percent biotite and minor amphibole. Chlorite occurs in intermediate to felsic metavolcanics metamorphosed under greenschist facies conditions.

CLASTIC AND CHEMICAL METASEDIMENTS

In the map area, metasediments occur as conglomerates and associated wackes: formed by local reworking of debris flows and tuffs in the Monument Bay formation; as fine-grained interflow metasediments in the Cochrane Island formation; and as laterally persistent horizons of wackes, with lesser iron formation, in the southeast half of the map area, that is, the Royal Island, Long Island, Betty Island, and Burnt Island formations (*see* Figure 2 and Figure 6). Conglomerates weather light buff, interflow metasediments weather medium grey-green and wacke weathers light grey to medium grey. Metasediments are massive to well foliated.

In the Monument Bay formation, reworking of heterolithic debris flows has produced localized clast-supported conglomerates from Monument Bay to Outer Bay. These conglomerates are characterized by rounded to well-rounded, 2 to 20 cm diameter clasts of aphyric, intermediate to felsic metavolcanics. These are mixed with a variety of similarly sized, angular to subangular, metavolcanic clasts that include mafic clinopyroxene-phyric clasts. The matrix is mainly a metamorphosed, immature, plagioclase wacke. Hornblende and biotite are metamorphic products of the clay-sized fraction.

These conglomerates are interbedded with volcanically derived feldspathic wacke and heterolithic debris flows. They are interpreted to represent local fluvial reworking of debris flows on the flank of a volcano. These conglomerates occur within a confined interval in the volcanic stratigraphy and may have been deposited during a temporary cessation of volcanism.

Thinly bedded argillaceous interflow metasediments are associated with tholeiitic, massive and pillowed flows in the Cochrane Island formation. Bedding is well developed and very delicate, suggesting quiet water deposition. Individual beds are less than 1 mm to about 10 cm thick. Local, soft sediment deformation occurs northeast of Separation Point.

The most widespread types of metasediment are wacke and lesser iron formation, associated with alkalic intermediate to felsic metavolcanics in the south half of the map area. Four wacke units are recognized as the Royal Island, Long Island, Betty Island and Burnt Island formations; it is probable that one or more of these units is repeated by folding or faulting.

Wacke horizons are composed mainly of thick-bedded quartz-feldspar wacke exhibiting complete

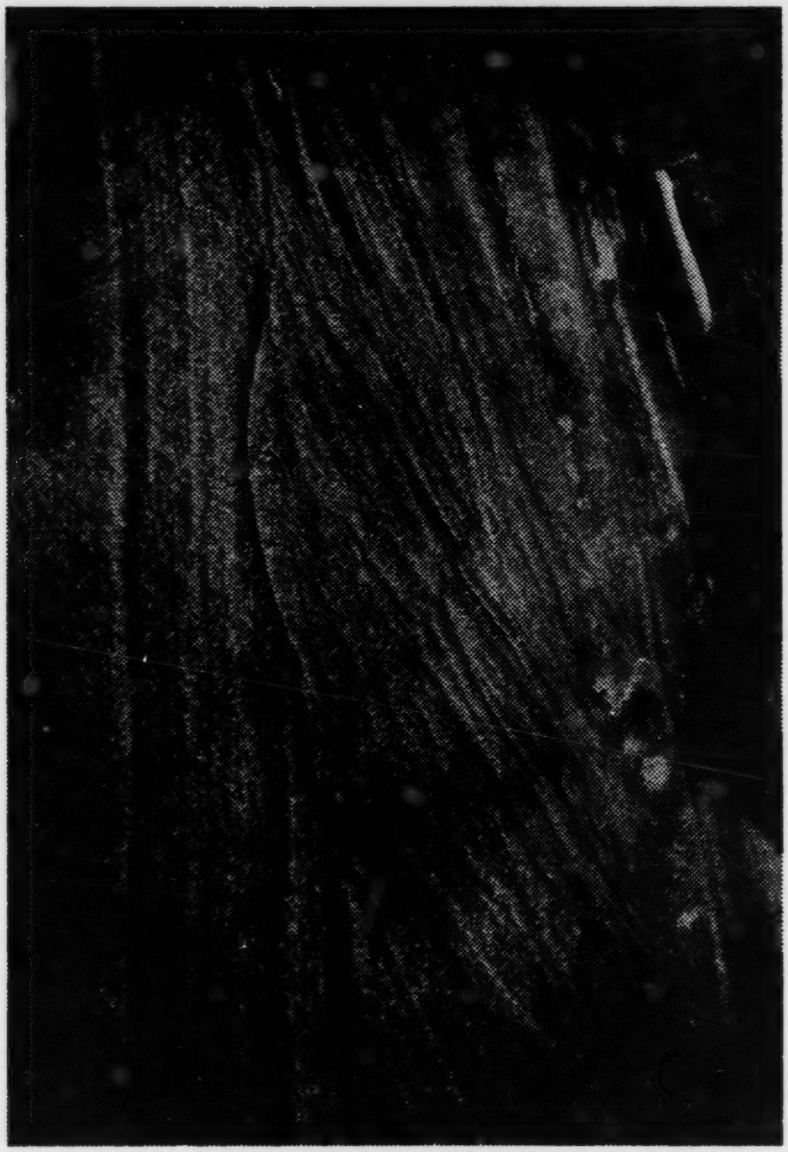

Photo 8. *Scour-and-fill structure, and cross-bedding in clinopyroxene-phyric tuffs, Separation Point formation, Separation Point. Flow direction from bottom to top (west to east).*

Bouma sequences (Photo 10). Bed thickness is generally 50 cm to 1.5 m, with the basal "A" division being 0.4 to 1.2 m thick and the upper, pelitic, "E" division making up the remaining 0.1 to 0.2 m of the bed. These wackes resemble, and have been correlated with, the Warclub group of metasediments on the east side of Lake of the Woods (Ayer 1988; Ayer et al. 1987). Several of the wacke beds contain ball-and-pillow structures defined by 3 to 5 cm diameter balls of sand-sized material within the upper pelitic portion of the bed.

Iron formation occurs within the Betty Island formation. It is particularly well developed near the east edge of the map area where metachert and meta-ironstone are interbedded with wacke. Bedding within the iron formation is up to 30 cm thick and highly contorted; this is possibly the result, at least in part, of soft sediment slumping.

Recrystallization has obscured primary mineralogy of all the metasediments, excepting the conglomerates and feldspathic wackes in Outer Bay. Where primary mineralogy is preserved, the wackes are characterized by abundant, broken, plagioclase crystals. The groundmass is a fine-grained, mainly recrystallized, granoblastic mosaic of quartz and feldspar grains with lesser biotite and chlorite.

Photo 9. *High-potassium calc-alkalic plagioclase-phyric pillow breccia, Johnston Passage formation, south of La Vérendrye Island.*

The thick-bedded wackes of the south part of the map area have been recrystallized and are now characterized by the presence of garnet, staurolite and andalusite porphyroblasts. Most conspicuous among these are 1 to 3 cm knots of sieve-textured andalusite which contain tiny inclusions of epidote, quartz, feldspar, and garnet. In some wackes the andalusite porphyroblasts have retrograded to aggregates of quartz, plagioclase, muscovite and chlorite. Biotite is ubiquitous, in amounts between 15 and 25 percent.

INTRUSIVE ROCKS

Metamorphosed Ultramafic Intrusive Rocks

Metamorphosed ultramafic intrusive rocks are confined to small occurrences in the Separation Point, Cochrane Island and Clipper Island formations (*see* Figure 6). They are metamorphosed pyroxenites that weather a medium to dark green colour and range from massive to schistose. The pyroxenites, and the gabbros with which they are associated, contain clinopyroxene crystals 5 to 10 mm in diameter. This suggests that the pyroxenites are basal cumulate portions of layered mafic-ultramafic sills. The marked similarity between the clinopyroxene crystals and clinopyroxene phenocrysts in adjacent mafic volcanic rocks is consistent with these sills being subvolcanic intrusions.

The ultramafic sills are 20 to 80 m thick. They are composed mainly of 75 to 90 percent light green amphibole after clinopyroxene, serpentine and lesser biotite, plagioclase, and opaque minerals.

Metamorphosed Mafic Intrusive Rocks

Metamorphosed mafic intrusive rocks are interpreted to represent synvolcanic sills. They are most abundant in the Cochrane Island formation, but also occur within the Separation Point and Clipper Island formations (*see* Figure 6). Both weathered and fresh surfaces are black. These mafic intrusive rocks are invariably massive and non-foliated; deformation is taken up along their margins or in narrow, discrete, internal shear zones less than 1 m wide.

Individual intrusions, which tend to be sill-like, range in thickness up to 350 m; most are less than 100 m thick. Colour indices range between 35 and 65, and textures range from medium-grained equigranular to inequigranular. Mafic sills are composed mainly of amphibole and plagioclase with accessory opaque minerals, epidote and carbonate. Porphyritic varieties contain 2 to 5 mm clinopyroxene phenocrysts pseudomorphed by hornblende, in a finer grained groundmass. Many of the units mapped as mafic sills within the Cochrane Island formation may be coarse-grained, massive mafic flows.

Metamorphosed Intermediate to Felsic Intrusive Rocks

Metamorphosed, intermediate to felsic plagioclase and quartz-plagioclase porphyry sills, up to 40 m wide, occur throughout the map area with the greatest proportion occurring in the Drift Island formation (*see* Figure 6). On the basis of textural similarity to clasts in spatially related pyroclastics, these sills are interpreted to be synvolcanic; some of the units mapped as sills may be flows. They range from massive to well foliated; weathered and fresh surfaces are light grey to buff.

Feldspar porphyry sills contain 10 to 30 percent, equant plagioclase phenocrysts, 2 to 4 mm in size, in a fine-grained mosaic of quartz and plagioclase, with minor biotite and opaque minerals. In addition to the plagioclase phenocrysts, quartz-feldspar porphyry sills contain 5 to 15 percent, embayed quartz phenocrysts of 2 to 5 mm diameter. Tiny needles of sillimanite occur in a feldspar porphyry sill at the northeast end of the La Vérendrye Island formation.

Alkalic Intrusive Rocks

A microcline-phyric hornblende syenite, which is a border phase of the Falcon Island igneous complex,

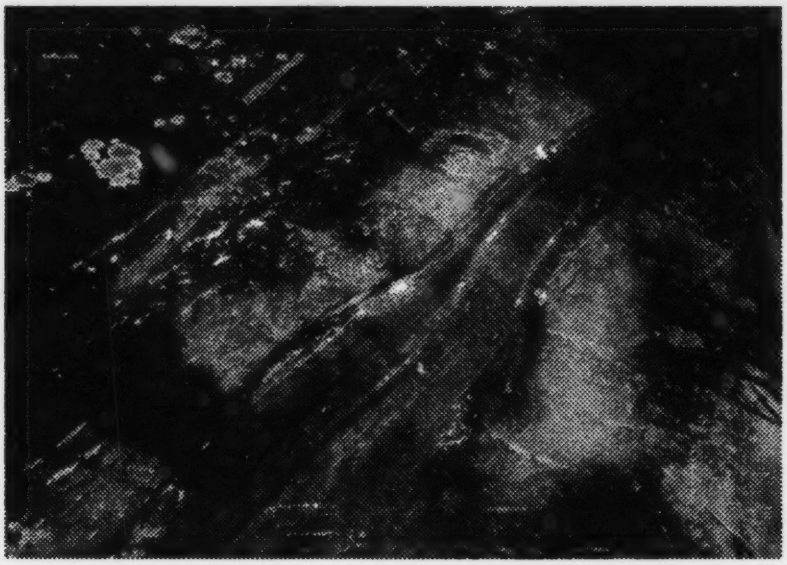

Photo 10. *Coarse, bedded wackes, Royal Island formation, north of La Vérendrye Island. Light grey beds are psammitic, darker beds with discontinuous quartz veins are pelitic.*

Photo 11. *Microcline-megacrystic syenite, southeast part of map area. Aligned microcline phenocrysts define a flow foliation in this marginal phase of the Falcon Island igneous complex.*

intrudes intermediate to felsic metavolcanics and metasediments in the southeast part of the map area (Photo 11). The Falcon Island igneous complex is a 10 km diameter, highly magnetic, intermediate to ultramafic alkalic intrusion, the core of which lies to the east of the Monument Bay map area (Ayer 1988; Blackburn 1981; ODM-GSC 1962). The syenitic border phase in the Monument Bay map area has a pronounced igneous foliation, defined by the alignment of tabular microcline phenocrysts, which trends parallel to its outer contact. The syenite is characterized by 40 to 60 percent, 1 to 2 cm long, microcline phenocrysts in a groundmass composed mainly of deep green hornblende and biotite. Clinopyroxene occurs as minor ragged cores to some hornblende crystals. Accessory phases are apatite, titanite and muscovite.

A suite of massive to foliated, biotite-bearing lamprophyre dikes occurs throughout the map area.

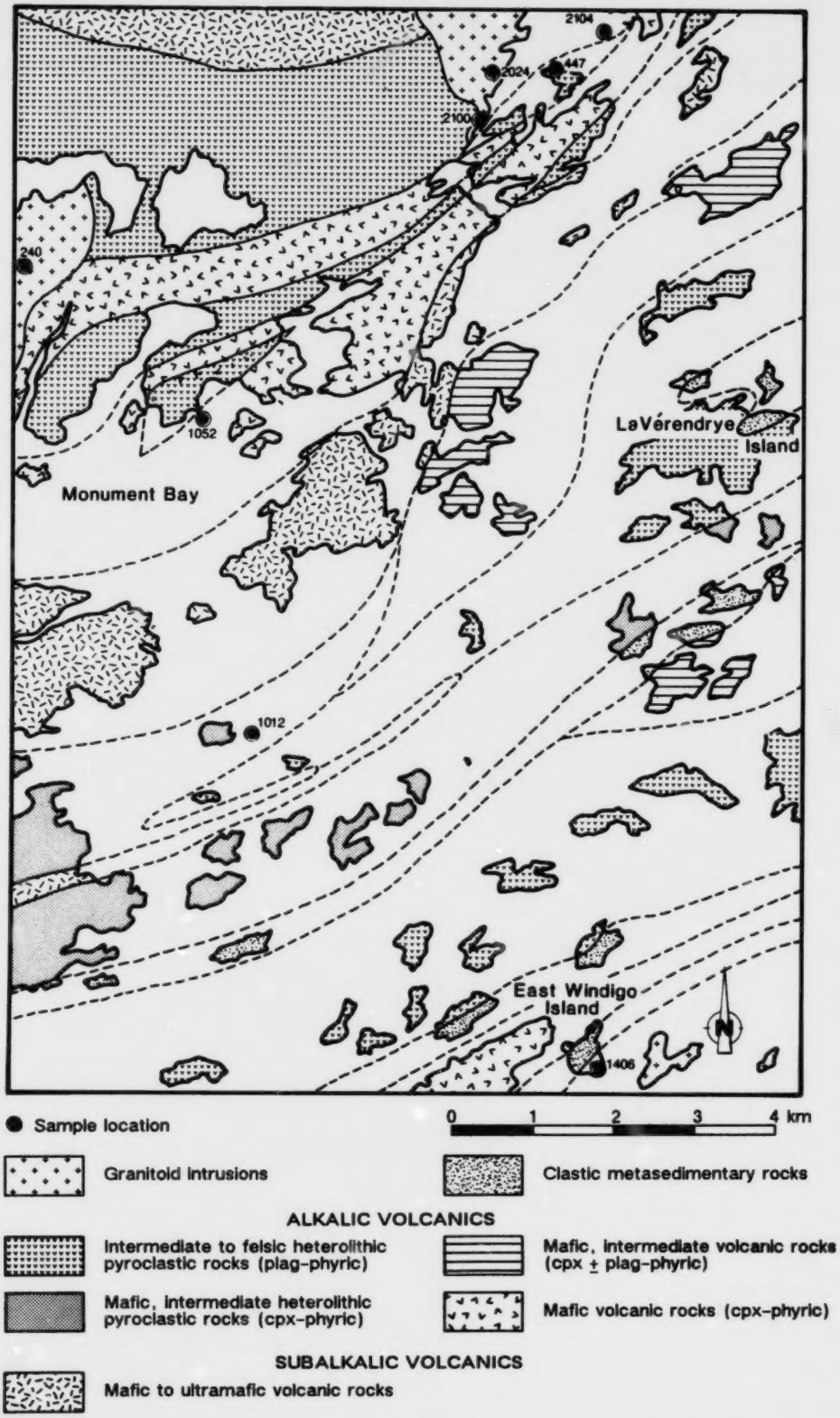

Figure 7. *Map showing the locations of stained (for potassium feldspar) slabs of granitoids, Monument Bay area.*

The greatest concentration of these rocks is within and adjacent to the tholeiitic metavolcanics of the Cochrane Island formation. The lamprophyres range in composition from monzodiorite to hornblendite, and in texture from fine grained to coarse grained to pegmatitic, and equigranular to porphyritic. Porphyritic phases include equant, centimetre-sized clinopyroxene phenocrysts which have been pseudomorphed by hornblende; or primary hornblende phenocrysts. Texturally, the clinopyroxene-phyric lamprophyres resemble clinopyroxene-phyric mafic alkalic metavolcanics. One fine-grained lamprophyre, from the Separation Point formation, is composed of 60 percent plagioclase laths, 30 to 35 percent biotite, 10 to 15 percent hornblende, 3 percent pyrite and 3 to 5 percent carbonate. This rock has an unusual texture, characterized by 1 to 8 mm diameter ocelli of plagioclase laths. Individual intrusions range from dikelets, less than 5 cm wide, to multiphase intrusions, up to 100 m wide.

Several lamprophyres are associated with chaotically brecciated, previously foliated country rock. This brecciation is interpreted to have been caused by hydrofracturing of roof rocks by volatiles exsolved during lamprophyre emplacement. The brecciation of the penetratively foliated country rock indicates posttectonic emplacement of the lamprophyres.

The age of the lamprophyre dikes is uncertain, but they appear to have a protracted history of emplacement from syn- to posttectonic.

Intermediate to Felsic Intrusive Rocks

Intermediate to felsic intrusive rocks occur as two distinct plutons and several smaller dike-like bodies

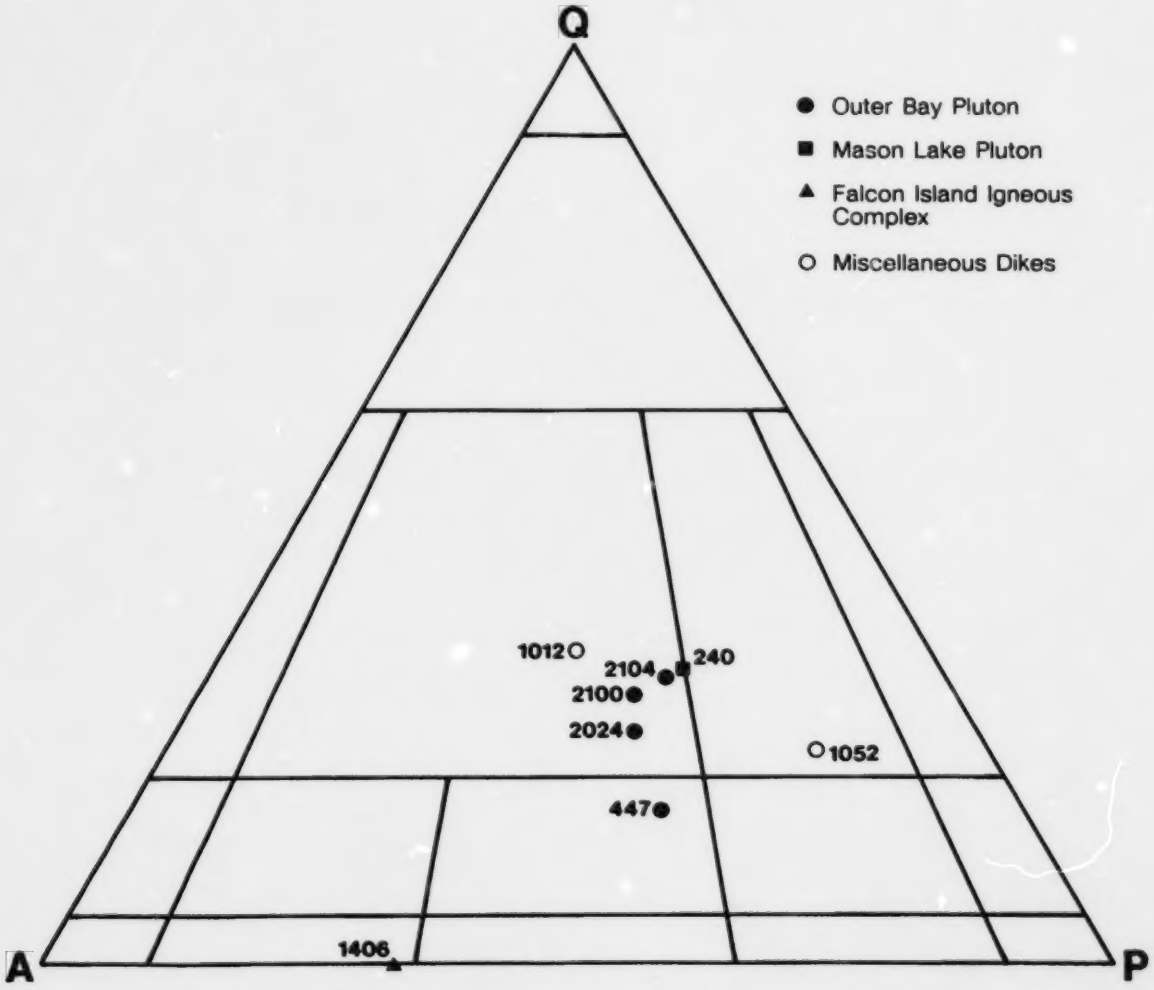

Figure 8. *Modal analyses of granitoid rocks on Quartz–Alkali Feldspar–Plagioclase ternary diagram (Streckeisen 1976), Monument Bay area.*

in the north part of the Monument Bay map area. All are composed mainly of medium- to coarse-grained hornblende-biotite granodiorite with lesser hornblende diorite and quartz diorite (Figure 7, Figure 8). The plutons are characterized by the presence of minor, 5 to 15 cm by 2 to 5 cm, fine-grained amphibolite xenoliths, especially evident near pluton margins. A weak fabric, defined by alignment of these mafic xenoliths and microcline megacrysts, occurs within these granodiorites, along and parallel with their margins, indicating fabric development during pluton emplacement.

The Mason Lake and Outer Bay plutons are texturally distinct from each other. The Mason Lake pluton has an inequigranular to quartz-phyric texture characterized by centimetre-sized quartz grains in a medium- to coarse-grained groundmass. There is little or no evidence of wall rock assimilation along the margins of the Mason Lake granodiorite. The Outer Bay pluton contains 5 to 35 percent microcline megacrysts, 0.5 to 1.5 cm in size, in a medium-grained groundmass. Hornblende diorite and quartz diorite phases occur along the south margin of the Outer Bay intrusion, indicating local wall rock assimilation. Epidote-hornblende hornfels has developed, in aureoles 250 m to 1 km wide, in country rocks adjacent to both intrusions.

Minor granodiorite, quartz diorite and diorite dikes, 1 to 100 m wide, intrude the metavolcanics, cutting foliation. Pegmatite and aplite intrusions characterize the contact zones of the Mason Lake and Outer Bay plutons.

Microcline phenocrysts in the Outer Bay pluton display grid twinning, and contain minor, small inclusions of plagioclase and hornblende. The groundmass is medium grained to coarse grained, and characterized by subhedral to euhedral plagioclase, weakly altered to saussurite; anhedral, interstitial quartz; and biotite and hornblende. Accessory phases include epidote, titanite, carbonate and opaque minerals.

Mafic Intrusive Rocks

Early Proterozoic, north-northwest-trending diabase dikes are a minor constituent of the map area. They are up to 20 m wide, aphanitic to medium grained, and have well defined, diabasic chill margins. Epidote-hornblende hornfels aureoles have developed in country rocks adjacent to these dikes. The width of the aureoles is proportional to dike width; none is greater than 20 m wide.

These dikes have diabasic textures characterized by 50 to 60 percent, 0.25 to 1 mm long, plagioclase laths interstitial to 0.5 to 2 mm sized anhedral, equant clinopyroxene crystals. Late crystallizing interstitial phases include hornblende (3 to 5 percent), quartz (2 to 3 percent), and opaque minerals (1 to 2 percent). Chlorite occurs as a minor alteration product of clinopyroxene.

These diabase dikes are part of the 2.1 Ga Kenora–Kabetogama swarm (Southwick and Day 1983; Halls 1986; Southwick and Halls 1987).

Geochemistry

INTRODUCTION

Samples of 74 rocks were analyzed for major elements and selected trace elements; 38 of these were subsequently analyzed for rare earth elements (REE). Care was taken in the field to sample the freshest and most representative parts of each rock unit. Individual clasts were sampled from coarse pyroclastic deposits. Results are presented in Tables 3 through 9; corresponding sample descriptions are listed in Table 10 and sample locations are shown on Figure 9.

All analyses were performed by the Geoscience Laboratories of the Ontario Geological Survey. Major elements were determined by X-ray fluorescence (XRF) on fused discs. Loss on ignition (LOI) was by gravimetric methods; carbon dioxide and sulphur were determined by infra-red spectrometry.

Beryllium, cobalt, copper, molybdenum, nickel, scandium, vanadium and zinc were analyzed by Inductively Coupled Plasma—Optical Emission Spectrometry (ICP/OES). Niobium, rubidium, strontium, thorium, ytterbium, and zirconium were analyzed by XRF. The rare earth elements (REEs) were analyzed by ion-exchange chromotography with ICP/OES.

The following discussion of geochemical results is organized according to rock units as mapped in the field.

METAVOLCANIC ROCKS

THOLEIITIC METAVOLCANIC ROCKS

Ultramafic and Mafic Metavolcanics

Four samples (0212, 0406, 1437, 1442) from the ultramafic metavolcanics were analyzed for major and selected trace elements. Two of these (0406, 1437) were analyzed for REEs (*see* Table 3). These ultramafic metavolcanics have a narrow compositional range: MgO: 11.6 to 11.9 percent, Ni: 300 to 315 ppm, Cr: 880 to 920 ppm, TiO_2: 0.6 percent, K_2O: <0.1 percent and P_2O_5: <0.05 percent (*see* Table 3, Figure 3). In these respects, ultramafic flows in the Monument Bay area resemble those in the Northwest Angle Inlet area (Morrice 1988). These analyses plot in the basaltic komatiite field on a cation plot (Jensen 1976) (*see* Figure 4) and in the tholeiitic field on an AFM plot (Irvine and Baragar 1971) (*see* Figure 5). On a chondrite-normalized REE diagram, these basaltic komatiites have patterns which are flat, to slightly depleted in light REE (LREE), at six to nine times chondritic values, with $(Ce/Yb)_N$ of 0.7 to 0.9 (Figure 10).

Nine samples (0235, 0405, 0584a, 1173, 1262, 1436, 1438, 1439, 1443) from mafic metavolcanics were analyzed. These samples are characterized by K_2O equal to 0.1 to 0.6 percent, and variable MgO (2.8 to 7.0 percent) and Cr (44 to 366 ppm) contents (*see* Table 3, Figure 3). Mafic metavolcanics plot in the tholeiite field on both the cation (Jensen 1976) and AFM diagrams (Irvine and Baragar 1971) (*see* Figure 4, Figure 5).

Rare earth elements were determined for four (0235, 0405, 1438, 1439) of the mafic metavolcanics. Chondrite-normalized REE patterns are flat, with $(Ce/Yb)_N$ of 0.9 to 1.2 at 10 to 15 times chondrites (Figure 11).

ALKALIC TO CALC-ALKALIC METAVOLCANICS

Mafic Metavolcanics

Twenty-one samples from the alkalic and calc-alkalic mafic metavolcanics were analyzed for major and selected trace elements. Six of these (0044, 0046, 0051, 0177, 0309, 1047) were analyzed for REE (*see* Table 4). Rock types analyzed include clinopyroxene-phyric flows and tuffs, plagioclase-phyric flows, and plagioclase-phyric clasts in tuff breccia units. These samples display a wide range in SiO_2 (47 to 60 percent), MgO (2.6 to 10.6 percent), K_2O (0.2 to 4.0 percent), and Cr (14 to 695 ppm) (*see* Table 4, Figure 3). Apparently both mafic and intermediate rocks are included in the alkalic mafic metavolcanics. Several samples plot in the "shoshonitic assemblage" field of Figure 3, confirming their alkalic nature.

Despite the wide range of K_2O contents, REE patterns are uniformly steeply inclined with $(Ce/Yb)_N$ of 4 to 14 (*see* Figure 11). The REEs, being relatively immobile, are generally considered to be a better indicator of parental magma compositions than the more mobile alkali elements. The steep REE patterns exhibited by these samples are characteristic of alkalic volcanics (e.g., Kay and Gast 1973), indicating that the samples with low K_2O contents are indeed alkalic in nature and may have experienced some potassium depletion.

Intermediate Metavolcanics

Eleven samples of intermediate metavolcanics were analyzed for major and trace elements; seven of these were also analyzed for REEs (*see* Table 5). These samples include plagioclase-phyric flows, and clasts from heterolithic and monolithic tuff breccia units; sample 0300 is from an intensely amphibolitized flow.

These samples display a wide range of compositions: SiO_2: 48 to 64 percent, CaO: 4.2 to 11.4 percent, and K_2O: 0.2 to 2.2 percent (*see* Table 5, Figure 3).

The seven samples have similar REE patterns. All are enriched in LREEs, with $(Ce/Yb)_N$ of 5 to 21. There is a pronounced flattening of the

chondrite-normalized REE distribution patterns at the heavy REE (HREE) end of Figure 12. Samples 0299 and 0300, which are from the same outcrop, represent an unaltered, and an intensely amphibolitized, plagioclase-phyric pillowed flow, respectively. Note that this alteration is characterized by considerable mobility of major elements, especially addition of CaO and MgO, and loss of K_2O, Na_2O and Al_2O_3 (*see* Table 5). The REEs, however, have been little affected as a result of this alteration, exhibiting only slight enrichment in the LREEs (*see* Figure 12).

Intermediate to Felsic Metavolcanics

The results of analysis of 18 samples of intermediate to felsic metavolcanics for major and selected trace elements are shown in Table 6; 4 of these were analyzed for REEs. These samples are mainly of clasts from tuff breccia units.

The composition of these rocks is not unusual: SiO_2 ranges from 60 to 73 percent; MgO, from 0.5 to 2.2 percent; and K_2O, from 0.2 to 2.9 percent (*see* Table 6, Figure 3). The REE patterns are steeply inclined, with $(Ce/Yb)_N$ of 5 to 24. Content of HREEs is especially low, at 1 to 7 times chondrites (*see* Figure 13).

INTRUSIVE ROCKS

METAMORPHOSED MAFIC INTRUSIVE ROCKS

Two samples of metamorphosed, mafic, synvolcanic sills were analyzed (*see* Table 7). Sample 0185 is medium-grained equigranular gabbro, and sample 0043 is mafic, feldspar porphyry containing centimetre-long, tabular plagioclase phenocrysts in a fine-grained groundmass. The major element content of sample 185 is similar to that of the tholeiitic mafic metavolcanics; it is probably a comagmatic, subvolcanic sill. This sample plots in the tholeiite fields of both cation and AFM diagrams (*see* Figure 4, Figure 5). Sample 0043, however, has a greater K_2O content and may be related to the alkalic suite of metavolcanics (*see* Figure 3).

METAMORPHOSED INTERMEDIATE TO FELSIC INTRUSIVE ROCKS

Three samples of metamorphosed intermediate to felsic intrusive rocks were analyzed for major and trace elements (*see* Table 8). All are similar geochemically, having greater than 64 percent SiO_2, and 2.6 to 3.5 percent K_2O. In many respects, these rocks are geochemically similar to the intermediate to felsic metavolcanics into which they intrude. However, the intrusive rocks have K_2O contents that are higher than for most of the intermediate to felsic metavolcanics. This may indicate that the intrusive rocks belong to the high-potassium, shoshonitic suite, of which samples 0034 and 0117 are metavolcanic members. This shoshonitic suite is distinct from calc-alkalic, intermediate to felsic metavolcanics which have lower K_2O contents (*see* Figure 3).

ALKALIC MAFIC INTRUSIVE ROCKS

Three samples (443, 1068, 1070) from a lamprophyric intrusion in the southeast part of Monument Bay were analyzed for major and trace elements (*see* Table 9). These samples show a wide range in Fe_2O_3 (8.3 to 17.9 percent), MgO (3.4 to 10.7 percent), K_2O (0.2 to 2.9 percent), and P_2O_5 (0.2 to 0.9 percent) content (*see* Table 9, Figure 3); Cr contents are low (up to 77 ppm).

DISCUSSION

An understanding of the geochemistry of the Monument Bay area builds on several features which were recognized in the Northwest Angle Inlet area (Morrice 1988). Of prime importance is the confirmation of two distinct suites of metavolcanic rocks, which can be readily identified in the field. The presence of centimetre-sized clinopyroxene phenocrysts in mafic metavolcanics, which resemble those phenocrysts found in Cenozoic alkalic basalts (e.g., Morrice and Gill 1986), serves to distinguish the alkalic and calc-alkalic basalts from the aphyric tholeiitic basalts. Geochemically, these clinopyroxene-phyric basalts are characterized by high K_2O contents (greater than one percent K_2O) and light-enriched REE patterns. In many respects they resemble the shoshonitic rock association (Joplin 1968). The tholeiitic basalts are characterized by low K_2O contents (less than 0.3 percent K_2O) and flat REE patterns.

At the felsic end of the K_2O–SiO_2 variation diagram, a wide spectrum of compositions are present (*see* Figure 7). Whether these rocks are derived from alkalic, calc-alkalic or tholeiitic parents is unclear, and beyond the scope of this report.

Similar clinopyroxene-phyric basalts have been documented at several other locations within the western Wabigoon Subprovince, including Sunshine Lake (Blackburn 1981, 1982; Teal 1979), Gibi Lake (Trowell 1986), Rainy River (Johns 1987), Chisholm Island (Ayer *et al.* 1987), near Sandybeach Lake northeast of Dryden (Berger 1987), and within the Crowduck Group of metasediments, north of Shoal Lake (M. Morrice, personal observations, 1987; Smith 1987).

Chemically, the clinopyroxene-phyric basalts from the Chisholm Island and Sandybeach Lake areas are different from those of the present area. They appear to be calc-alkalic in composition rather than alkalic (J. Ayer and B. Berger, geologists, Ontario Geological Survey, personal communication). Reports of similar alkalic metavolcanics elsewhere in the Superior Province include Cooke and Moorehouse (1969), Shegelski (1980), Brooks *et al.* (1982), and Corkery and Cameron (1987).

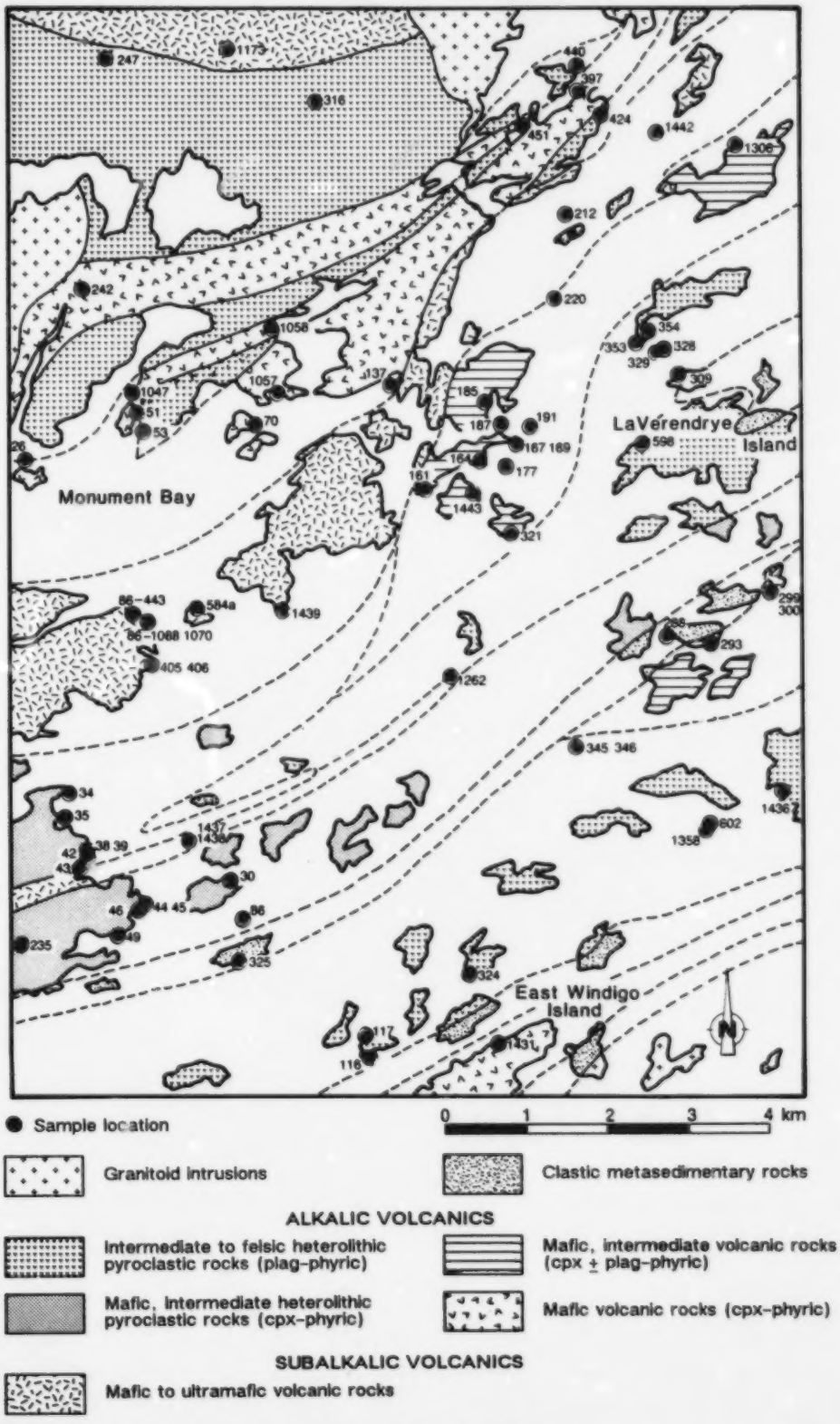

Figure 9. *Locations of whole rock geochemistry samples, Monument Bay area.*

TABLE 3. GEOCHEMISTRY OF MAFIC TO ULTRAMAFIC METAVOLCANICS.

Whole Rock Analyses
MAJOR ELEMENT OXIDES

Sample No.	0212	1442	1439	0405	584A	1438
SiO_2	46.80	48.00	51.40	51.20	51.60	51.70
Al_2O_3	13.20	13.50	13.70	14.10	13.50	14.60
Fe_2O_3	12.00	11.80	10.40	12.50	11.50	11.90
MgO	11.90	11.60	8.84	7.61	7.04	6.75
CaO	9.69	9.22	10.90	11.10	11.30	10.30
Na_2O	1.34	0.96	1.36	1.16	1.82	1.63
K_2O	0.03	0.05	0.17	0.14	0.20	0.13
TiO_2	0.56	0.58	0.57	0.71	0.67	1.08
P_2O_5	0.04	0.04	0.03	0.06	0.05	0.10
MnO	0.18	0.17	0.18	0.21	0.22	0.17
CO_2	0.14	0.15	0.91	0.08	0.78	0.10
S	0.07	0.05	0.01	0.05	0.06	0.06
LOI	3.30	4.10	2.00	0.60	1.00	0.70

TRACE ELEMENTS

Co	61	60	45	46	44	42
Cr	880	920	455	300	366	264
Cu	81	110	12	109	110	79
Ni	300	315	96	74	78	62
Pb	-10	-10	-10	-10	-10	-10
Zn	85	90	97	115	94	97
Be	-1	-1	1	1	-1	1
Co	62		46	55		42
Cu	82		15	123		87
Mo	-10	-10	-10	11	-10	-10
Ni	306		106	92		69
Sc	36	36	49	54	46	48
Sr	108	101	104	115	82	119
V	225	220	263	299	288	320
Y	17	15	16	22	19	29
Zn	70		97	117		94
Nb	-5	-5	-5	-5	-5	-5
Rb	-5	-5	-5	-5	-5	-5
Sr	115	107	110	127	88	131
Y	21	17	15	19	19	34
Zr	66	64	62	73	70	110
Th	-10	11	-10	-10	-10	-10
Pr			820 ppb	1.10		1.80
Sm			1.30	1.70		3.20
Eu			560 ppb	590 ppb		1.10
Gd			1.90	2.30		4
Tb			320 ppb	440 ppb		720 ppb
Dy			2.20	2.80		4.90
Ho			520 ppb	640 ppb		1
Er			1.40	1.90		3
Tm			240 ppb	280 ppb		460 ppb
Yb			1.60	1.80		3
Lu			270 ppb	250 ppb		440 ppb
Ce			6.60	8		14
La			3.20	3.10		5.10
Nd			4	5.60		10
Y			12	16		28

All sample numbers are formally preceded by 87MGM.

TABLE 3. Continued.

MAJOR ELEMENT OXIDES						
Sample No.	0406	1437	1443	1262	1173	0235
SiO_2	51.50	51.50	46.20	53.10	52.80	50.40
Al_2O_3	14.80	15.20	14.80	14.70	15.80	16.60
Fe_2O_3	12.60	11.70	9.99	14.40	10.00	13.30
MgO	6.18	5.68	5.66	3.80	3.63	3.08
CaO	10.10	10.80	15.30	7.15	6.28	10.60
Na_2O	1.90	1.91	1.85	4.39	3.20	2.45
K_2O	0.15	0.19	0.13	0.60	1.36	0.49
TiO_2	0.79	0.96	0.54	1.04	0.72	1.17
P_2O_5	0.07	0.07	0.07	0.14	0.16	0.14
MnO	0.19	0.26	0.18	0.27	0.18	0.19
CO_2	0.09	0.31	3.08	0.29	3.38	0.31
S	0.03	0.01	0.24	0.09	0.03	0.02
LOI	0.50	0.70	3.50	0.30	5.30	0.50
TRACE ELEMENTS						
Co	45	45	44	36	33	37
Cr	82	322	354	44	41	38
Cu	117	25	93	100	54	156
Ni	54	130	98	14	39	29
Pb	-10	-10	-10	-10	-10	17
Zn	100	99	77	132	91	120
Be	1	1	-1	-1	1	2
Co	45	49			35	35
Cu	124	27			62	169
Mo	-10	-10	-10	-10	-10	-10
Ni	62	137			47	32
Sc	42	43	33	38	25	34
Sr	117	118	285	197	420	235
V	282	279	241	343	190	305
Y	18	26	12	29	20	26
Zn	100	100			94	114
Nb	-5	-5	-5	-5	-5	-5
Rb	-5	-5	-5	15	38	-5
Sr	132	127	305	214	403	242
Y	22	30	14	34	21	32
Zr	79	103	79	128	139	116
Th	-10	-10	-10	-10	-10	-10
Pr	1.10	1.80			5.20	2.90
Sm	1.80	2.80			4.10	3.50
Eu	690 ppb	1.10			1.20	1.10
Gd	2.50	3.90			3.70	4
Tb	430 ppb	690 ppb			580 ppb	700 ppb
Dy	3	4.20			3.50	4.50
Ho	730 ppb	980 ppb			740 ppb	1
Er	2	2.80			2.30	3
Tm	310 ppb	450 ppb			350 ppb	450 ppb
Yb	1.90	2.70			2.20	2.90
Lu	310 ppb	460 ppb			380 ppb	420 ppb
Ce	8.10	13			46	20
La	3.10.	5			19	8.40
Nd	5.70	8.80			23	13
Y	16	24			20	27

TABLE 3. Continued.

MAJOR ELEMENT OXIDES	
Sample No.	**1436**
SiO_2	49.80
Al_2O_3	16.80
Fe_2O_3	13.00
MgO	2.84
CaO	10.80
Na_2O	2.89
K_2O	0.50
TiO_2	1.16
P_2O_5	0.19
MnO	0.25
CO_2	0.24
S	0.12
LOI	0.50

TRACE ELEMENTS	
Co	49
Cr	196
Cu	47
Ni	70
Pb	-10
Zn	137
Be	-1
Mo	-10
Sc	36
Sr	362
V	267
Y	24
Nb	-5
Rb	-5
Sr	366
Y	29
Zr	119
Th	-10

major element oxides in weight percent
trace elements in ppm except as noted

TABLE 4. GEOCHEMISTRY OF ALKALIC MAFIC METAVOLCANICS.

Whole Rock Analyses
MAJOR ELEMENT OXIDES

Sample No.	0038	1431	1058	0164	0046	0242
SiO_2	47.20	50.20	50.80	54.30	50.70	47.60
Al_2O_3	11.60	13.10	13.90	14.40	17.10	14.50
Fe_2O_3	10.20	11.10	9.51	9.81	8.90	11.30
MgO	10.60	8.34	7.11	6.46	6.04	5.90
CaO	12.70	10.20	8.54	8.69	10.90	8.84
Na_2O	1.35	1.95	1.96	2.43	2.76	2.11
K_2O	0.48	1.90	2.83	0.92	0.20	3.99
TiO_2	0.60	0.95	0.65	0.67	0.67	0.83
P_2O_5	0.20	0.41	0.16	0.21	0.20	0.45
MnO	0.14	0.19	0.15	0.16	0.19	0.19
CO_2	1.70	0.31	2.37	0.28	0.86	2.23
S	0.02	0.01	0.01	0.05	0.01	0.01
LOI	2.40	1.40	3.10	0.70	1.20	2.80

TRACE ELEMENTS

Co	44	39	35	41	36	35
Cr	695	178	270	278	143	156
Cu	89	20	87	65	87	131
Ni	235	63	53	108	86	38
Pb	-10	-10	-10	-10	-10	-10
Zn	82	110	85	83	91	117
Be	-1	2	-1	-1	-1	-1
Co	39	41	37	43	34	36
Cu	85	23	88	65	84	133
Mo	-10	-10	-10	-10	-10	-10
Ni	196	75	59	122	84	45
Sc	36	36	31	27	34	24
Sr	422	592	677	413	426	935
V	247	250	213	191	246	227
Y	14	24	15	15	15	21
Zn	59	110	76	77	71	102
Nb	-5	-5	-5	-5	-5	-5
Rb	8	51	74	30	-5	111
Sr	422	582	669	416	415	968
Y	17	23	15	17	18	21
Zr	117	145	140	134	120	175
Th	-10	12	-10	-10	-10	16
Pr		10			4.10	
Sm		8.50			3.20	
Eu		2.30			1	
Gd		6.30			2.90	
Tb		880 ppb			440 ppb	
Dy		4.40			2.80	
Ho		820 ppb			600 ppb	
Er		2.30			1.70	
Tm		320 ppb			250 ppb	
Yb		2.10			1.70	
Lu		300 ppb			250 ppb	
Ce		83			30	
La		38			13	
Nd		42			15	
Y		22			16	

All sample numbers are formally preceded by 87MGM.

TABLE 4. Continued.

MAJOR ELEMENT OXIDES						
Sample No.	**0424**	**0177**	**0309**	**0397**	**1047**	**0045**
SiO_2	53.70	55.70	54.00	53.20	53.90	49.00
Al_2O_3	14.00	16.40	16.40	13.10	13.70	17.30
Fe_2O_3	8.46	9.04	8.60	8.08	8.52	10.60
MgO	5.40	5.31	5.12	5.12	4.53	4.15
CaO	6.67	7.67	9.88	9.40	9.50	9.94
Na_2O	3.66	2.83	2.51	2.77	2.42	3.47
K_2O	3.59	0.36	0.32	2.55	1.71	0.87
TiO_2	0.72	0.64	0.88	0.58	0.60	0.88
P_2O_5	0.41	0.14	0.49	0.27	0.18	0.42
MnO	0.14	0.14	0.19	0.12	0.16	0.15
CO_2	1.10	0.09	0.37	3.42	3.87	2.00
S	0.01	0.01	0.01	0.02	0.01	0.01
LOI	1.80	1.00	0.80	4.80	4.50	2.20
TRACE ELEMENTS						
Co	33	31	37	31	31	33
Cr	174	111	195	316	222	174
Cu	44	16	59	75	86	32
Ni	41	60	51	73	55	85
Pb	10	-10	-10	-10	-10	-10
Zn	103	71	100	85	72	104
Be	-1	-1	-1	-1	-1	-1
Co		32	43		29	30
Cu		11	64		82	28
Mo	-10	-10	-10	-10	-10	-10
Ni		70	61		60	87
Sc	24	14	21	26	22	23
Sr	725	273	662	682	495	572
V	193	154	218	186	167	246
Y	20	13	19	18	12	16
Zn		56	87		58	84
Nb	-5	-5	-5	-5	-5	-5
Rb	102	7	8	59	55	27
Sr	690	304	672	637	521	570
Y	20	18	25	16	14	21
Zr	183	118	178	154	129	163
Th	15	-10	-10	10	-10	-10
Pr		2.90	13		3.30	
Sm		2.50	8.60		2.70	
Eu		770 ppb	2.20		730 ppb	
Gd		2.40	5.70		2.40	
Tb		350 ppb	700 ppb		320 ppb	
Dy		2.30	3.80		2	
Ho		490 ppb	730 ppb		420 ppb	
Er		1.40	1.90		1.20	
Tm		200 ppb	260 ppb		170 ppb	
Yb		1.30	1.60		1.10	
Lu		200 ppb	230 ppb		170 ppb	
Ce		22	92		25	
L						
Nd		12	50		12	
Y		13	21		12	

TABLE 4. Continued.

MAJOR ELEMENT OXIDES						
Sample No.	0051	0451	0070	0325	0187	0247
SiO_2	60.00	55.10	50.40	52.80	56.30	55.30
Al_2O_3	13.80	13.70	16.10	14.70	14.20	16.40
Fe_2O_3	6.17	11.10	11.10	12.40	7.62	9.01
MgO	4.07	4.44	4.05	3.98	3.64	3.37
CaO	5.16	8.34	11.00	8.83	7.26	6.24
Na_2O	3.64	3.71	3.08	3.83	2.62	2.86
K_2O	2.20	0.25	0.21	1.38	2.63	1.31
TiO_2	0.54	1.49	1.36	0.97	0.56	0.76
P_2O_5	0.14	0.15	0.11	0.36	0.13	0.14
MnO	0.12	0.15	0.16	0.19	0.13	0.16
CO_2	2.59	0.10	1.70	0.16	2.91	2.34
S	0.01	0.01	0.01	0.06	0.01	0.01
LOI	2.90	0.60	1.70	0.50	3.20	4.20
TRACE ELEMENTS						
Co	21	37	29	37	27	31
Cr	118	185	186	167	107	36
Cu	31	26	7	62	55	36
Ni	34	91	46	98	54	40
Pb	-10	14	-10	-10	-10	18
Zn	65	148	98	129	84	85
Be	-1	2	-1	2	-1	1
Co	18	36	27	37	28	32
Cu	28	28	-1	69	54	43
Mo	-10	-10	-10	-10	-10	-10
Ni	39	93	50	103	62	46
Sc	18	22	22	23	18	24
Sr	487	390	311	1146	550	575
V	136	150	191	209	136	181
Y	10	19	15	21	12	21
Zn	50	149	83	128	77	85
Nb	-5	-5	-5	-5	-5	-5
Rb	60	-5	-5	19	73	41
Sr	454	396	314	1145	528	536
Y	13	21	21	21	12	21
Zr	137	146	124	142	143	143
Th	-10	-10	-10	-10	-10	-10
Pr	4.60	4.20		15		5.50
Sm	3.20	4.80		8.90		4.30
Eu	900 ppb	1.50		2.40		1.10
Gd	2.40	4.60		5.90		3.70
Tb	330 ppb	660 ppb		720 ppb		560 ppb
Dy	2	3.50		3.90		3.60
Ho	400 ppb	670 ppb		750 ppb		750 ppb
Er	1.10	1.70		2		2.20
Tm	160 ppb	210 ppb		290 ppb		310 ppb
Yb	1	1.40		1.80		1.90
Lu	140 ppb	200 ppb		250 ppb		280 ppb
Ce	37	34		130		47
La	17	13		54		20
Nd	16	21		61		23
Y	11	19		21		21

TABLE 4. Continued.

MAJOR ELEMENT OXIDES				
Sample No.	**0044**	**0321**	**0329**	**0030**
SiO_2	51.50	51.20	54.00	57.80
Al_2O_3	16.00	15.60	16.40	14.80
Fe_2O_3	9.78	10.40	7.37	9.55
MgO	3.21	3.11	2.66	2.58
CaO	9.63	9.23	10.30	5.38
Na_2O	3.91	2.60	4.08	3.26
K_2O	0.60	1.41	0.22	2.58
TiO_2	0.93	0.75	0.71	1.10
P_2O_5	0.43	0.29	0.22	0.69
MnO	0.15	0.21	0.36	0.15
CO_2	2.55	3.44	2.78	0.32
S	0.01	0.01	0.02	0.06
LOI	2.70	3.70	3.10	1.00
TRACE ELEMENTS				
Co	28	35	50	22
Cr	197	54	59	14
Cu	30	49	61	49
Ni	84	53	77	8
Pb	-10	-10	-10	-10
Zn	97	96	75	132
Be	-1	-1	-1	-1
Co	26	34		
Cu	26	47		
Mo	-10	-10	-10	-10
Ni	88	57		
Sc	24	18	31	16
Sr	587	179	685	533
V	242	164	226	148
Y	17	17	19	35
Zn	76	85		
Nb	-5	-5	-5	9
Rb	12	47	-5	52
Sr	575	198	692	556
Y	23	21	22	45
Zr	164	130	134	276
Th	-10	-10	-10	13
Pr	10			
Sm	6.80			
Eu	1.70			
Gd	4.90			
Tb	640 B			
Dy	3.50			
Ho	710 B			
Er	1.90			
Tm	290 B			
Yb	1.80			
Lu	280 B			
Ce	76			
La	33			
Nd	38			
Y	19			

major element oxides in weight percent trace elements in ppm except as noted

TABLE 5. GEOCHEMISTRY OF INTERMEDIATE METAVOLCANICS.

Whole Rock Analyses
MAJOR ELEMENT OXIDES

Sample No.	0300	1358	1306	0042	0220	0049
SiO_2	48.40	52.30	52.30	59.40	53.60	57.50
Al_2O_3	15.30	15.30	16.70	15.00	17.30	15.10
Fe_2O_3	11.70	8.63	9.81	6.89	9.42	9.33
MgO	5.53	4.30	4.28	4.10	3.51	3.10
CaO	11.40	7.27	7.30	6.43	8.76	4.45
Na_2O	2.89	3.09	3.09	4.78	4.46	3.70
K_2O	0.37	3.12	0.35	0.87	0.21	2.24
TiO_2	0.85	1.17	0.67	0.49	0.98	1.05
P_2O_5	0.34	0.37	0.16	0.10	0.51	0.66
MnO	0.22	0.12	0.14	0.10	0.15	0.16
CO_2	0.97	3.11	2.40	0.73	0.22	0.61
S	0.02	0.01	0.01	0.01	0.01	0.05
LOI	1.30	3.90	5.10	0.70	0.70	0.90

TRACE ELEMENTS

Co	34	52	34	24	28	17
Cr	118	191	53	134	56	-10
Cu	28	21	76	53	61	37
Ni	88	161	50	56	63	-5
Pb	-10	-10	-10	-10	-10	-10
Zn	134	78	96	85	92	111
Be	-1	1	1	-1	-1	-1
Co	38	53	34	22	31	15
Cu	24	18	79	52	60	37
Mo	-10	-10	-10	-10	-10	-10
Ni	97	163	59	53	70	7
Sc	21	28	23	19	11	18
Sr	766	468	541	476	644	750
V	169	219	157	147	168	172
Y	21	22	15	10	16	23
Zn	114	78	95	67	74	97
Nb	-5	-5	-5	-5	5	6
Rb	-5	96	7	20	-5	50
Sr	824	459	513	463	689	758
Y	28	22	18	12	22	32
Zr	168	120	122	132	186	200
Th	-10	-10	-10	-10	11	-10
Pr	11	10	4.20		11	15
Sm	6.90	7.50	3.40		7	9.70
Eu	1.90	2.10	1.10		1.90	2.50
Gd	5.30	6.20	2.90		4.70	6.70
Tb	700 ppb	810 ppb	500 ppb		600 ppb	860 ppb
Dy	4.20	4.10	2.80		3.30	4.70
Ho	840 ppb	840 ppb	560 ppb		650 ppb	930 ppb
Er	2.30	2.10	1.80		1.60	2.50
Tm	320 ppb	300 ppb	240 ppb		230 ppb	360 ppb
Yb	2.20	1.90	1.50		1.30	2.40
Lu	300 ppb	290 ppb	210 ppb		190 ppb	360 ppb
Ce	88	86	35		84	110
La	38	36	15		33	45
Nd	43	45	18		41	56
Y	23	21	15		18	25

All sample numbers are formally preceded by 87MGM.

TABLE 5. Continued.

MAJOR ELEMENT OXIDES						
Sample No.	**0299**	**0169**	**0137**	**0191**	**0167**	**0293**
SiO_2	51.70	58.90	64.40	51.20	57.70	60.10
Al_2O_3	18.80	16.30	15.00	20.80	16.60	16.00
Fe_2O_3	11.30	7.66	3.87	8.45	9.43	7.01
MgO	3.03	2.94	2.88	2.83	2.24	1.92
CaO	6.06	5.02	4.17	8.46	6.54	5.79
Na_2O	4.25	4.47	3.99	4.01	2.38	5.32
K_2O	1.84	1.47	1.85	0.61	1.92	0.47
TiO_2	0.97	0.60	0.39	0.71	0.97	0.75
P_2O_5	0.29	0.22	0.11	0.19	0.32	0.30
MnO	0.17	0.13	0.07	0.11	0.14	0.13
CO_2	0.55	0.52	1.82	0.28	0.22	0.19
S	0.04	0.01	0.01	0.72	0.03	0.04
LOI	0.60	0.60	1.90	1.10	0.40	0.30
TRACE ELEMENTS						
Co	24	21	12	28	27	21
Cr	36	15	97	34	19	40
Cu	71	27	23	94	69	77
Ni	39	14	42	32	22	24
Pb	-10	-10	-10	-10	-10	-10
Zn	188	82	71	61	93	89
Be	-1	-1	-1	-1	-1	-1
Co	28	23	11	29	30	
Cu	72	21	21	105	64	
Mo	-10	-10	-10	-10	-10	-10
Ni	46	19	49	38	28	
Sc	13	14	7	13	13	13
Sr	460	528	553	443	363	402
V	172	125	64	174	192	117
Y	17	15	7	12	16	21
Zn	183	73	58	47	74	
Nb	-5	-5	-5	-5	-5	-5
Rb	58	42	44	13	67	10
Sr	509	534	538	465	403	399
Y	28	19	9	16	21	25
Zr	153	171	158	128	154	149
Th	-10	13	-10	12	-10	-10
Pr	7.70		4.60	4.30	7.40	
Sm	5.20		2.50	3.30	5.30	
Eu	1.50		680 ppb	1	1.50	
Gd	4.30		1.60	2.70	4.10	
Tb	640 ppb		200 ppb	390 ppb	590 ppb	
Dy	3.90		1.10	2.40	3.30	
Ho	830 ppb		190 ppb	520 ppb	670 ppb	
Er	2.40		460 ppb	1.50	1.70	
Tm	330 ppb		70 ppb	200 ppb	250 ppb	
Yb	2.10		440 ppb	1.30	1.60	
Lu	290 ppb		70 ppb	190 ppb	220 ppb	
Ce	59		40	31	54	
La	26		20	13	22	
Nd	29		16	17	29	
Y	23		5.40	14	19	

TABLE 5. Continued.

MAJOR ELEMENT OXIDES	
Sample No.	**0086**
SiO_2	60.60
Al_2O_3	17.50
Fe_2O_3	6.54
MgO	1.71
CaO	6.27
Na_2O	3.46
K_2O	0.77
TiO_2	0.79
P_2O_5	0.22
MnO	0.18
CO_2	0.71
S	0.03
LOI	1.00

TRACE ELEMENTS	
Co	39
Cr	51
Cu	128
Ni	60
Pb	-10
Zn	76
Be	-1
Co	36
Cu	132
Mo	-10
Ni	63
Sc	21
Sr	426
V	186
Y	11
Zn	61
Nb	-5
Rb	38
Sr	425
Y	16
Zr	134
Th	-10

major element oxides in weight percent trace elements in ppm except as noted

TABLE 6. GEOCHEMISTRY OF INTERMEDIATE TO FELSIC METAVOLCANICS.

Whole Rock Analyses
MAJOR ELEMENT OXIDES

Sample No.	0598	0353	0039	0161	0034	0053
SiO_2	53.00	56.40	62.90	60.10	60.90	69.10
Al_2O_3	13.40	16.40	15.70	16.40	14.40	13.10
Fe_2O_3	17.20	8.72	5.98	7.35	6.52	3.99
MgO	3.08	3.08	2.24	2.15	2.13	2.13
CaO	8.84	8.75	6.13	5.71	4.08	4.13
Na_2O	0.62	2.85	4.54	3.94	4.19	3.54
K_2O	0.25	0.24	0.45	1.05	2.24	1.27
TiO_2	0.48	0.76	0.41	0.56	0.92	0.47
P_2O_5	0.13	0.28	0.16	0.17	0.40	0.12
MnO	0.61	0.13	0.08	0.11	0.14	0.07
CO_2	0.93	1.31	0.76	1.40	2.41	0.45
S	0.11	0.01	0.01	0.01	0.02	0.07
LOI	1.10	1.80	0.60	1.30	2.40	0.70

TRACE ELEMENTS

Co	25	27	16	16	9	16
Cr	60	70	41	30	-10	77
Cu	20	7	49	47	11	30
Ni	30	36	28	10	-5	37
Pb	-10	-10	-10	-10	-10	10
Zn	94	99	59	65	82	57
Be	-1	1	-1	-1	-1	-1
Co	25	29	15	16	7	13
Cu	21	9	47	40	6	31
Mo	-10	-10	-10	-10	-10	-10
Ni	37	43	29	16	5	39
Sc	17	23	11	10	15	9
Sr	205	434	745	444	463	726
V	96	164	104	144	77	82
Y	13	21	8	11	25	6
Zn	88	105	45	50	66	46
Nb	-5	-5	-5	-5	7	-5
Rb	-5	-5	8	25	49	36
Sr	215	423	726	504	437	667
Y	12	25	11	14	36	7
Zr	113	160	154	154	252	156
Th	12	11	-10	-10	11	-10
Pr	3	6.40		3.90		4.40
Sm	2.30	4.90		3.10		3
Eu	740 ppb	1.40		930 ppb		800 ppb
Gd	2.30	4		2.40		2.10
Tb	330 ppb	610 ppb		350 ppb		260 ppb
Dy	1.90	3.40		2.20		1.30
Ho	450 ppb	710 ppb		470 ppb		250 ppb
Er	1.30	2		1.30		660 B
Tm	190 ppb	300 ppb		190 ppb		80 ppb
Yb	1.30	1.80		1.30		550 B
Lu	200 ppb	280 ppb		200 ppb		70 ppb
Ce	27	55		29		35
La	13	24		12		16
Nd	13	26		15		16
Y	12	19		12		6.70

All sample numbers are formally preceded by 87MGM.

TABLE 6. Continued.

MAJOR ELEMENT OXIDES						
Sample No.	0026	1057	0328	0035	0117	0354
SiO_2	67.80	69.70	62.80	73.00	67.20	64.20
Al_2O_3	14.80	13.60	15.20	13.80	14.60	16.20
Fe_2O_3	4.07	2.60	2.89	1.59	5.16	2.62
MgO	1.98	1.23	0.91	0.74	0.67	0.62
CaO	2.74	2.65	7.70	4.49	3.63	5.61
Na_2O	5.21	6.14	3.72	4.78	1.90	5.31
K_2O	1.56	0.87	1.00	0.25	2.93	0.73
TiO_2	0.36	0.31	0.67	0.35	0.40	0.52
P_2O_5	0.08	0.10	0.15	0.12	0.27	0.09
MnO	0.08	0.06	0.08	0.07	0.16	0.08
CO_2	0.43	1.19	3.12	1.32	1.22	2.33
S	0.01	0.01	0.01	0.01	0.01	0.01
LOI	0.70	1.20	3.50	1.10	1.40	2.70
TRACE ELEMENTS						
Co	10	9	7	-5	10	5
Cr	44	52	10	77	43	48
Cu	31	25	29	22	7	14
Ni	24	19	-5	-5	25	7
Pb	-10	20	-10	-10	13	-10
Zn	42	40	31	37	87	18
Be	-1	-1	1	-1	-1	-1
Co	9	8	9	2	10	
Cu	29	54	29	19	5	
Mo	-10	-10	-10	-10	-10	-10
Ni	24	24	9	9	30	
Sc	6	6	12	6	15	8
Sr	350	598	467	530	733	479
V	66	52	84	52	81	104
Y	6	7	14	4	13	11
Zn	31	43	37	30	76	
Nb	-5	-5	-5	-5	-5	-5
Rb	47	19	24	7	60	27
Sr	390	548	419	506	731	461
Y	11	8	16	8	15	13
Zr	151	146	136	133	183	140
Th	-10	-10	-10	-10	11	-10
Pr			4.40		16	
Sm			3.40		7.50	
Eu			990 ppb		1.80	
Gd			2.80		4.20	
Tb			420 ppb		470 ppb	
Dy			2.30		2.40	
Ho			510 ppb		450 ppb	
Er			1.30		1	
Tm			200 ppb		170 ppb	
Yb			1.20		1.20	
Lu			160 ppb		180 ppb	
Ce			38		125	
La			18		60	
Nd			17		54	
Y			12		14	

TABLE 6. Continued.

MAJOR ELEMENT OXIDES					
Sample No.	**0602**	**0316**	**0346**	**0345**	**0324**
SiO_2	71.50	73.30	73.00	70.60	70.10
Al_2O_3	15.00	14.60	14.80	15.30	15.00
Fe_2O_3	1.64	1.10	2.02	1.91	2.21
MgO	0.53	0.50	0.29	0.18	0.11
CaO	2.46	1.93	1.94	2.78	2.03
Na_2O	4.76	3.28	5.27	5.00	5.76
K_2O	2.36	2.13	1.28	1.33	1.64
TiO_2	0.25	0.26	0.39	0.41	0.36
P_2O_5	0.10	0.07	0.12	0.10	0.14
MnO	0.03	0.03	0.05	0.06	0.05
CO_2	0.93	0.68	0.11	0.48	0.98
S	0.01	0.01	0.01	0.01	0.01
LOI	1.30	1.40	0.60	0.70	1.60
TRACE ELEMENTS					
Co	-5	-5	-5	-5	-5
Cr	22	-10	54	60	12
Cu	6	5	8	-5	8
Ni	8	-5	12	10	-5
Pb	-10	-10	-10	-10	-10
Zn	29	15	22	27	23
Be	1	-1	-1	-1	1
Co	6	-1	6	6	4
Cu	6	7	5	6	9
Mo	-10	-10	-10	-10	-10
Ni	13	5	17	16	6
Sc	4	1	3	6	3
Sr	609	376	352	456	1055
V	29	16	33	47	27
Y	5	5	5	7	11
Zn	38	19	31	36	32
Nb	-5	-5	-5	-5	-5
Rb	41	43	21	22	40
Sr	543	365	322	399	951
Y	6	6	8	10	12
Zr	129	134	125	132	162
Th	-10	-10	-10	-10	10
Pr	4.50	2.50	3	3.10	17
Sm	2.50	1.50	1.90	2	8.30
Eu	720 ppb	440 ppb	610 ppb	660 ppb	1.90
Gd	1.50	950 ppb	1.50	1.50	4.50
Tb	180 ppb	110 ppb	180 ppb	220 ppb	510 ppb
Dy	800 ppb	550 ppb	830 ppb	1.10	2.40
Ho	150 ppb	90 ppb	140 ppb	200 ppb	400 ppb
Er	380 ppb	220 ppb	330 ppb	520 ppb	960 ppb
Tm	70 ppb	-50 ppb	-50 ppb	60 ppb	130 ppb
Yb	390 ppb	240 ppb	340 ppb	440 ppb	740 ppb
Lu	60 ppb	-50 ppb	-50 ppb	60 ppb	120 ppb
Ce	40	22	29	31	155
La	20	11	15	16	81
Nd	17	8.50	11	12	56
Y	4	3	4	6.30	11

major element oxides in weight percent trace elements in ppm except as noted

TABLE 7. GEOCHEMISTRY OF METAMORPHOSED MAFIC INTRUSIVE ROCKS.

Whole Rock Analyses
MAJOR ELEMENT OXIDES

Sample No.	0185	0043
SiO_2	47.60	51.00
Al_2O_3	15.90	16.50
Fe_2O_3	11.40	10.40
MgO	8.01	5.56
CaO	12.20	9.80
Na_2O	1.46	3.11
K_2O	0.19	0.74
TiO_2	0.61	0.58
P_2O_5	0.08	0.07
MnO	0.19	0.19
CO_2	0.12	0.07
S	0.07	0.03
LOI	1.20	0.70

TRACE ELEMENTS

Co	45	36
Cr	367	111
Cu	71	80
Ni	95	48
Pb	-10	-10
Zn	75	87
Be	-1	-1
Co	45	33
Cu	70	80
Mo	-10	-10
Ni	105	46
Sc	40	34
Sr	297	290
V	251	202
Y	13	19
Zn	65	65
Nb	-5	-5
Rb	-5	20
Sr	308	289
Y	16	24
Zr	82	109
Th	-10	-10

All sample numbers are formally preceded by 87MGM.
major element oxides in weight percent trace elements in ppm except as noted

TABLE 8. GEOCHEMISTRY OF METAMORPHOSED FELSIC TO INTERMEDIATE INTRUSIVE ROCKS.

Whole Rock Analyses
MAJOR ELEMENT OXIDES

Sample No.	0288	0116	0440
SiO_2	65.20	64.10	69.90
Al_2O_3	14.40	16.90	16.90
Fe_2O_3	8.41	4.80	0.71
MgO	1.11	0.58	0.26
CaO	5.27	2.38	2.69
Na_2O	1.40	4.89	4.39
K_2O	1.45	3.46	2.57
TiO_2	0.78	0.38	0.35
P_2O_5	0.23	0.28	0.15
MnO	0.16	0.08	0.02
CO_2	0.41	0.54	0.41
S	0.01	0.04	0.10
LOI	0.80	1.00	1.20

TRACE ELEMENTS

Co	10	11	5
Cr	-10	52	41
Cu	7	27	29
Ni	-5	20	16
Pb	25	10	12
Zn	180	92	15
Be	2	-1	-1
Co	11	11	
Cu	9	26	
Mo	-10	-10	-10
Ni	6	27	
Sc	12	8	-1
Sr	389	1260	609
V	14	86	63
Y	44	12	7
Zn	182	84	
Nb	-5	-5	-5
Rb	36	76	73
Sr	373	1280	603
Y	51	12	7
Zr	245	187	178
Th	-10	16	15
Pr	11		
Sm	8.40		
Eu	2.40		
Gd	8.80		
Tb	1.40		
Dy	7.80		
Ho	1.80		
Er	4.60		
Tm	730 B		
Yb	4.70		
Lu	730 B		
Ce	97		
La	42		
Nd	48		
Y	45		

All sample numbers are formally preceded by 87MGM.
major element oxides in weight percent trace elements in ppm except as noted

TABLE 9. GEOCHEMISTRY OF METAMORPHOSED ALKALIC MAFIC INTRUSIVE ROCKS.

Whole Rock Analyses
MAJOR ELEMENT OXIDES

Sample No.	1068	1070	0443
SiO_2	49.60	50.20	44.30
Al_2O_3	10.70	13.60	10.60
Fe_2O_3	8.32	14.50	17.90
MgO	10.70	3.39	4.05
CaO	8.76	10.40	8.38
Na_2O	2.48	2.77	4.60
K_2O	2.91	0.24	1.89
TiO_2	1.00	1.96	0.88
P_2O_5	0.75	0.18	0.89
MnO	0.12	0.28	0.19
CO_2	3.04	1.84	5.35
S	0.02	0.38	0.19
LOI	4.30	1.50	5.20
TRACE ELEMENTS			
Co	42	42	35
Cr	29	77	-10
Cu	104	89	25
Ni	93	41	5
Pb	28	-10	-10
Zn	79	144	96
Nb	-5	-5	-5
Rb	147	-5	105
Sr	349	151	533
Y	21	46	24
Zr	125	132	186
Th	10	-10	-10

All sample numbers are formally preceded by 86MGM.
major element oxides in weight percent trace elements in ppm except as noted

TABLE 10. DESCRIPTIONS OF WHOLE ROCK GEOCHEMISTRY SAMPLES, MONUMENT BAY AREA.

Sample No. (87MGM-xx)	Sample Description
Mafic to ultramafic metavolcanics	
0212	pillowed basaltic komatiite
0235	plagioclase-phyric pillow basalt; 25% plagioclase (2-4mm)
0405	massive basalt; 6 m below pillow contact
0406	pillow basalt
0584a	core of pillow
1173	mafic tuff/lapilli tuff; pyroclastic flow?
1262	variolitic pillowed komatiite; polysutured, amygdaloidal
1436	plagioclase-phyric pillow basalt
1437	pillowed basalt; top of compound flow
1438	massive basalt; base of compound flow
1439	massive basalt; pyroxene spinifex
1442	pillowed basaltic komatiite
1443	pillow basalt; "leopard rock"
Mafic metavolcanics	
0030	tuff; quartz-plagioclase-biotite sch, 30-35% biotite
0038	clinopyroxene cumulate tuff; ultramafic
0044	trachytic clast in heterolith tuff breccia; 20% plagioclase, 1% clinopyroxene
0045	trachytic clast in heterolith tuff breccia; 15% plagioclase
0046	clinopyroxene(5-7%)- and plagioclase (10%)-phyric pillow basalt
0051	alkalic mafic-intermediate tuff
0070	mafic hyaloclastite; amygdaloidal
0164	alkalic tuff; coarse bedded, gabbroic-looking
0177	clinopyroxene- and plagioclase-phyric flow; lava lake?
0187	mafic tuff; magnetic
0242	clinopyroxene-phyric, massive mafic flow
0309	clinopyroxene-phyric pillowed mafic flow
0321	mafic tuffs; amphibolitized
0325	clinopyroxene-phyric pillowed mafic flow; epidotized
0329	vesicular pillowed intermediate flow; aphyric
0397	amygdaloidal clinopyroxene-phyric mafic clast in pillow breccia
0424	autobrecciated, clinopyroxene-phyric mafic flow
0451	trachytic clast in monolithic tuff breccia
1047	clinopyroxene-phyric, pillowed mafic flow
1058	clinopyroxene-phyric massive mafic flow
1431	clinopyroxene-phyric mafic tuffs
Intermediate metavolcanics	
0042	intermediate clast, 6x30 cm, from mafic to intermediate tuff breccia; with clinopyroxene cumulate clot
0049	lapilli tuff; ash flow?, clinopyroxene- and plagioclase-phyric, pumice-bearing
0086	plagioclase-phyric (10%) pillowed mafic flow; 5-10% garnet porphyroblasts
0137	clinopyroxene-phyric intermediate flow; calcite amygdules?, biotite wisps, silicified?
0167	plagioclase-phyric pillowed flow
0169	plagioclase-phyric massive flow
0191	intermediate tuff; 15-20% tabular plagioclase phenocrysts
0220	intermediate dike; 15-20% tabular plagioclase phenocrysts
0293	plagioclase-phyric pillowed flow
0299	plagioclase-phyric pillowed intermediate flow
0300	amphibolitized equivalent of Sample 299
1306	plagioclase-phyric pillowed flow
1358	plagioclase-phyric pillowed flow; amygdaloidal
Intermediate to felsic metavolcanics	
0026	intermediate tuff
0034	feldspar porphyry; intrusive?, ash flow?
0035	aphyric intermediate-felsic clast in heterolithic tuff breccia
0039	aphyric intermediate clast in heterolithic tuff breccia; just north of Sample 38
0053	intermediate clinopyroxene-phyric clast in heterolithic tuff breccia
0117	plagioclase-phyric clast in heterolithic tuff breccia
0161	intermediate clast in heterolithic, intermediate to felsic tuff breccia; clinopyroxenite clot
0247	monolithic intermediate lapilli tuff; with pumice clasts?
0316	monolithic intermediate-felsic tuff breccia; quartz-feldspar porphyry
0324	felsic clast in heterolithic tuff breccia
0328	aphyric intermediate-felsic clast in tuff breccia
0345	quartz-feldspar porphyry clast in heterolithic tuff breccia
0346	feldspar porphyry clast in heterolithic tuff breccia; adjacent to Sample 345
0353	intermediate clast in heterolithic tuff breccia; hornblende-bearing (porphyroblastic?, porphyritic?)
0354	aphyric intermediate clast in heterolithic tuff breccia
0598	garnet-amphibole rock; 10-25% garnet porphyroblasts
0602	quartz-feldspar porphyry; massive flow?, sill?
1057	rounded clast in conglomerate
Mafic intermediate intrusive rocks	
0043	mafic feldspar-porphyry sill; tabular plagioclase phenocrysts
0185	gabbro dike
Intermediate to felsic intrusive rocks	
0116	massive feldspar porphyry
0288	quartz-plagioclase-biotite-garnet gneiss; altered intrusion?
0440	feldspar porphyry sill
Alkalic mafic intrusive rocks (86MGM-xx)	
0443	coarse-grained monzodiorite phase; lamprophyric complex
1068	chill margin; lamprophyric complex
1070	hornblende porphyry; lamprophyric complex

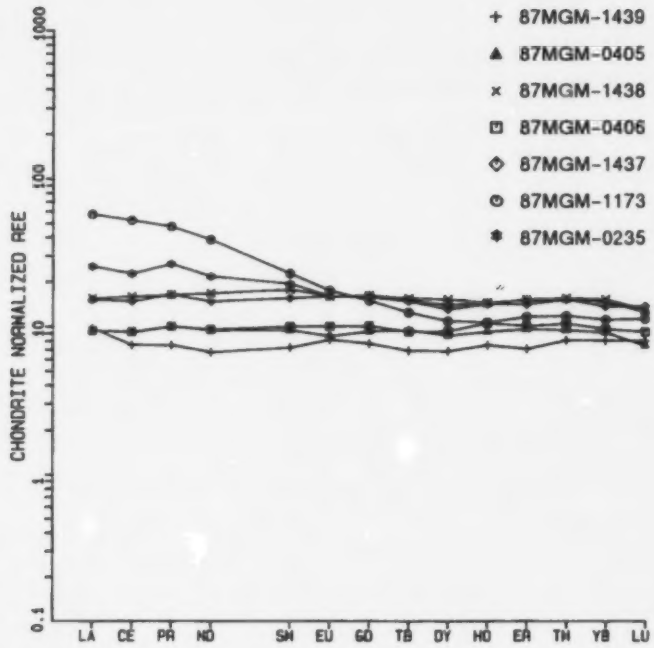

Figure 10. *REE diagram–tholeiitic mafic to ultramafic metavolcanics, Monument Bay area.*

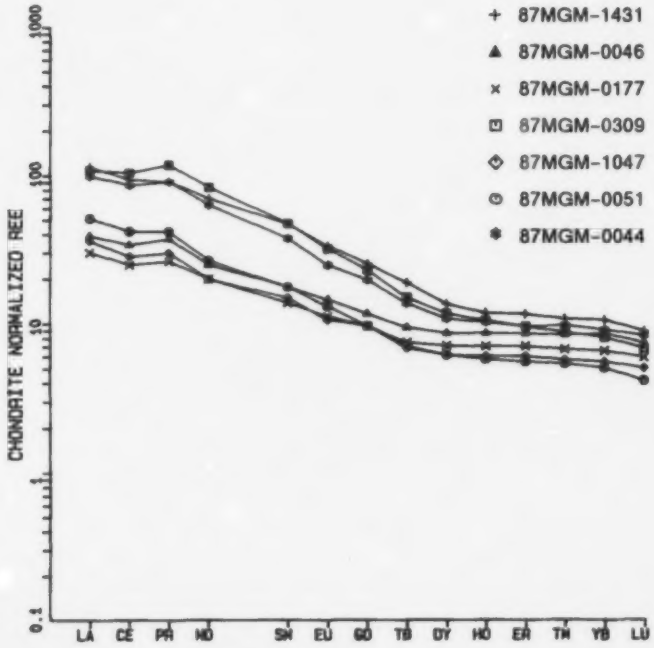

Figure 11. *REE diagram–alkalic mafic metavolcanics, Monument Bay area.*

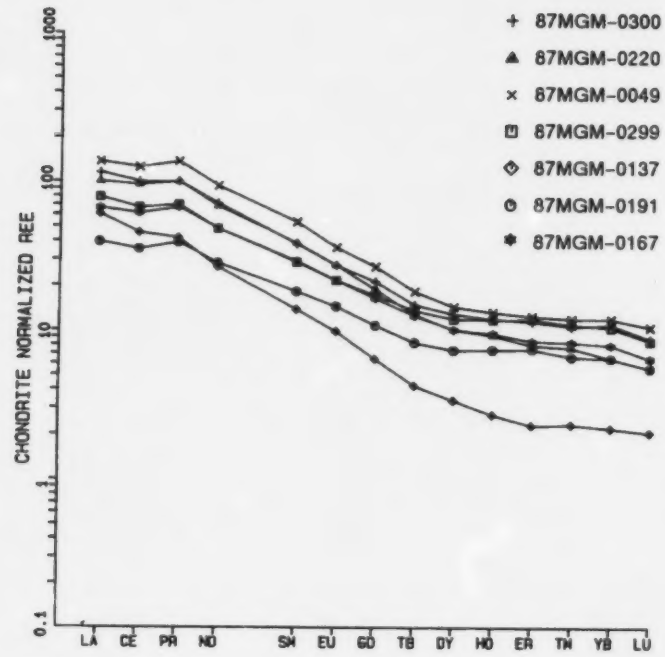

Figure 12. *REE diagram–alkalic and calc-alkalic intermediate metavolcanics, Monument Bay area.*

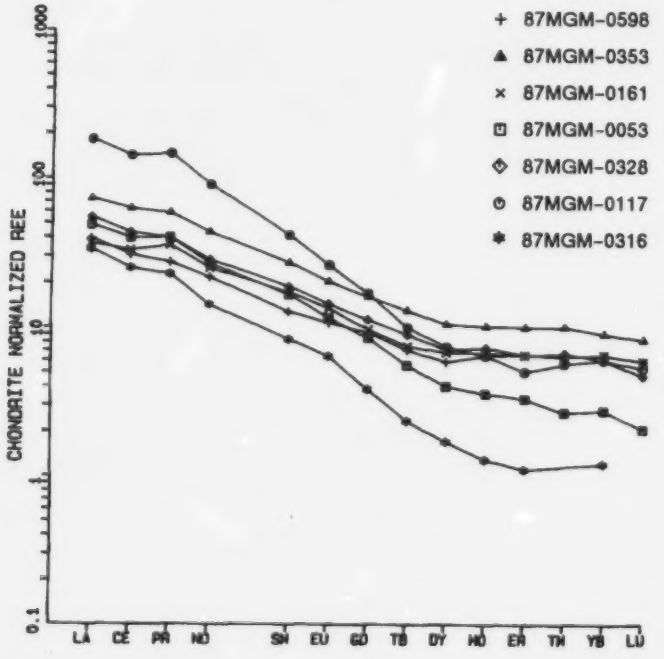

Figure 13. *REE diagram–alkalic and calc-alkalic intermediate to felsic metavolcanics, Monument Bay area.*

Structure, Metamorphism and Alteration

STRUCTURE

Reliable facing indicators, including shapes of pillows and contact relationships in flows and graded bedding, cross bedding, scour-and-fill structures and bomb sags in pyroclastics, are unevenly preserved in the map area. Well-preserved, southeast facing directions dominate the north half of the map area. Facing reversals in the central part of the map area define two synclines and an intervening anticline (*see* Figure 2). Both small-scale and related larger scale folds are characterized by axial planar cleavage and axes which plunge steeply to the west. Recrystallization has destroyed tops indicators in the southeast part of the map area, but repetition of stratigraphy by folding and/or faulting is suggested by the presence of several similar wacke horizons.

Most supracrustal rocks in the map area have a well developed foliation which trends east to northeast, except where deflected around granitic plutons. Two ages of foliation are recognized: a dominate, pervasive, early (F_1), east to northeast-trending foliation, which is usually a schistosity but may be a gneissosity locally; and a later, locally developed, fracture and crenulation cleavage (F_2). This later cleavage is best observed in the metasediments of the Royal Island formation where it trends at 120° to 140° and dips steeply. Except at fold closures northeast of La Vérendrye Island, F_1 foliation is generally parallel or near-parallel to layering.

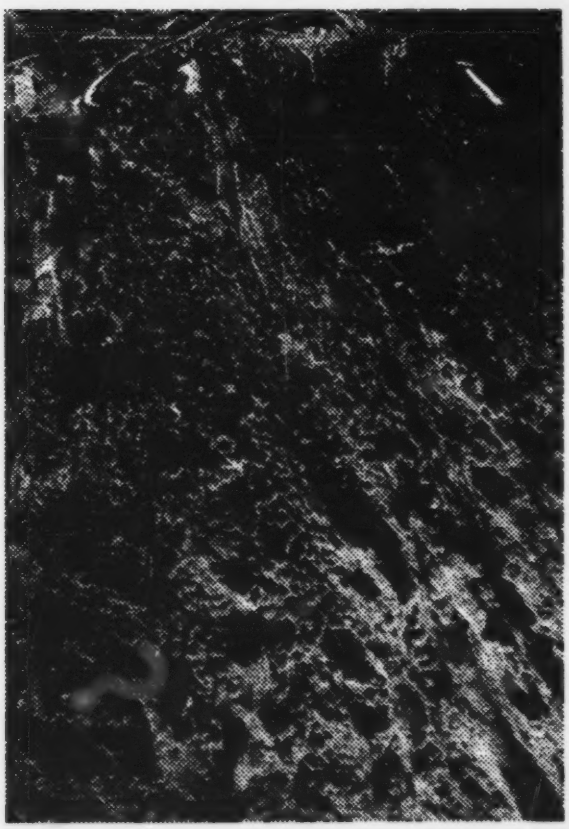

Photo 12. *Sheared and carbonatized tholeiitic mafic metavolcanics within the Monument Bay deformation zone, north of Separation Point.*

Photo 13. *Quartz-carbonate-pyrite vein within a shear zone in mafic metavolcanics, north of Separation Point.*

Shallow (30° to 50°) dips characterize F_1 foliations in the vicinity of Monument Bay, where dips are to the south, and in the southwestern part of the map area, where dips are to the north. An explanation for the shallow dips in the Monument Bay area is speculative, but they may be the result of a reorientation of originally steeply dipping foliation by processes related to the east-trending Monument Bay deformation zone.

The shallow, north-dipping foliations in the south part of the map area are consistent with the Sabaskong Batholith having a broad, shallow-dipping shoulder. This is suggested by the wide thermal

Photo 14. *Minor sinistral offset of F_1 foliation along 070° trending shear fracture, Drift Island formation, Drift Island.*

Photo 15. *Anastomosing shear fractures in intermediate to felsic sill caused by rotation of conjugate shear fractures, Drift Island formation.*

metamorphism aureole along the northern margin of the Sabaskong Batholith.

Mineral and stretching lineations are defined by the preferred orientation of prismatic hornblende crystals, recrystallized and stretched plagioclase and clinopyroxene phenocrysts in mafic and intermediate metavolcanics, and elongate clasts in pyroclastic rocks. Lineations, so defined, generally plunge steeply south to southeast down the dip of the F_1 foliation, throughout the map area.

The most prominent deformation zone in the map area is the 50 to 200 m wide east- to northeast-trending Monument Bay deformation zone (MBDZ) (Photo 12). The MBDZ continues west into the Northwest Angle Inlet map area and northeast into the Western Peninsula and Chisholm Island areas, where it joins with a splay from the Pipestone–Cameron Fault zone (Buck 1986; Ayer *et al.* 1987). Rocks within this fault zone are variably sheared, and carbonatized or amphibolitized.

Photo 16. *Folded and migmatized metasediments, Betty Island formation, Ike Island.*

Kinematic indicators are steeply dipping S-C fabrics, subvertical extensional crenulation cleavage, Z-folds with moderately to steeply plunging axes, asymmetric rotation of phenocrysts, asymmetric rotation of boudins with steeply dipping axes, and bending of rock units along the MBDZ south and west of Monument Bay (Morrice and MacMaster 1987). These indicate that this is predominately a zone of flattening, i.e., pure shear, with a minor, possibly late, subhorizontal, predominantly dextral component of simple shear. This is consistent with a northwest-directed maximum compressive stress.

Discrete shear zones up to 2 m wide are defined by an increase in intensity of schistosity and carbonate alteration. They occur throughout the map area but are best developed within, and adjacent to, the MBDZ where the shear zones trend approximately east, at an angle to the northeast-trending MBDZ. Many of these shear zones host quartz-carbonate-pyrite veins (Photo 13), several of which contain anomalous gold concentrations and are discussed below.

Deformation of intermediate to felsic metavolcanics in the southeast part of the map area is characterized by the development of steeply dipping, conjugate shear fractures trending 070° and 110°. These are bisected by the regional foliation, indicating that the shear fractures and foliation developed

Photo 17. *Preferential alteration of hyaloclastic matrix of pillow breccia by hornblende and garnet; clasts are only weakly to moderately altered; Johnston Passage formation, north of Falcon Island.*

under the same regional stress regime. In local areas, minor subhorizontal sinistral movement has occurred along the 070° fracture direction (Photo 14). Elsewhere, with increased flattening, these shear fractures rotate, until near parallel, into an anastomosing network (Photo 15). Individual fractures, up to 0.5 cm thick, appear to have been accentuated by mylonitization and alteration. In the thin section the fractures have been observed to be annealed but are finer grained than the adjacent undeformed host.

METAMORPHISM

Amphibolite facies mineral assemblages characterize the rocks in most of the map area, with the amphibolite-greenschist facies transition trending approximately southeast across the northern part of the map area (Figure 14). Blue-green hornblende is prevalent in mafic metavolcanics that have been metamorphosed to amphibolite facies grade. Within pelitic metasediments, biotite is abundant and andalusite, garnet and muscovite porphyroblasts are ubiquitous; porphyroblastic staurolite occurs locally. Andalusite occurs as sieve-textured knots, 0.5 to 2 cm in diameter. Garnet porphyroblasts are anhedral sieve-textured clots that range in diameter from 0.2 to 1 cm; muscovite porphyroblasts are 1 to 5 mm across, and staurolite is present as small euhedral porphyroblasts less than 5 mm long.

Migmatitic pelitic metasediments in the southeastern part of the map area are characterized by discontinuous layers and lenses of quartz-plagioclase leucosome with intervening biotite-rich melanosome. Leucosome is up to 3 cm thick, and constitutes up to 50 percent of the rock (Photo 16).

Greenschist mineral assemblages in mafic metavolcanics are characterized by actinolite, chlorite and carbonate.

Sillimanite occurs as tiny needles within a feldspar porphyry sill which intrudes intermediate to felsic pyroclastics in the northeast part of the map area. The presence of sillimanite may indicate assimilation of pelitic sediments by the feldspar porphyry.

Intense recrystallization of the supracrustals in the southern part of the map area, and the extensive development of amphibolite grade metamorphic assemblages, are related to thermal effects of the Sabaskong Batholith (Blackburn 1981). A similarly

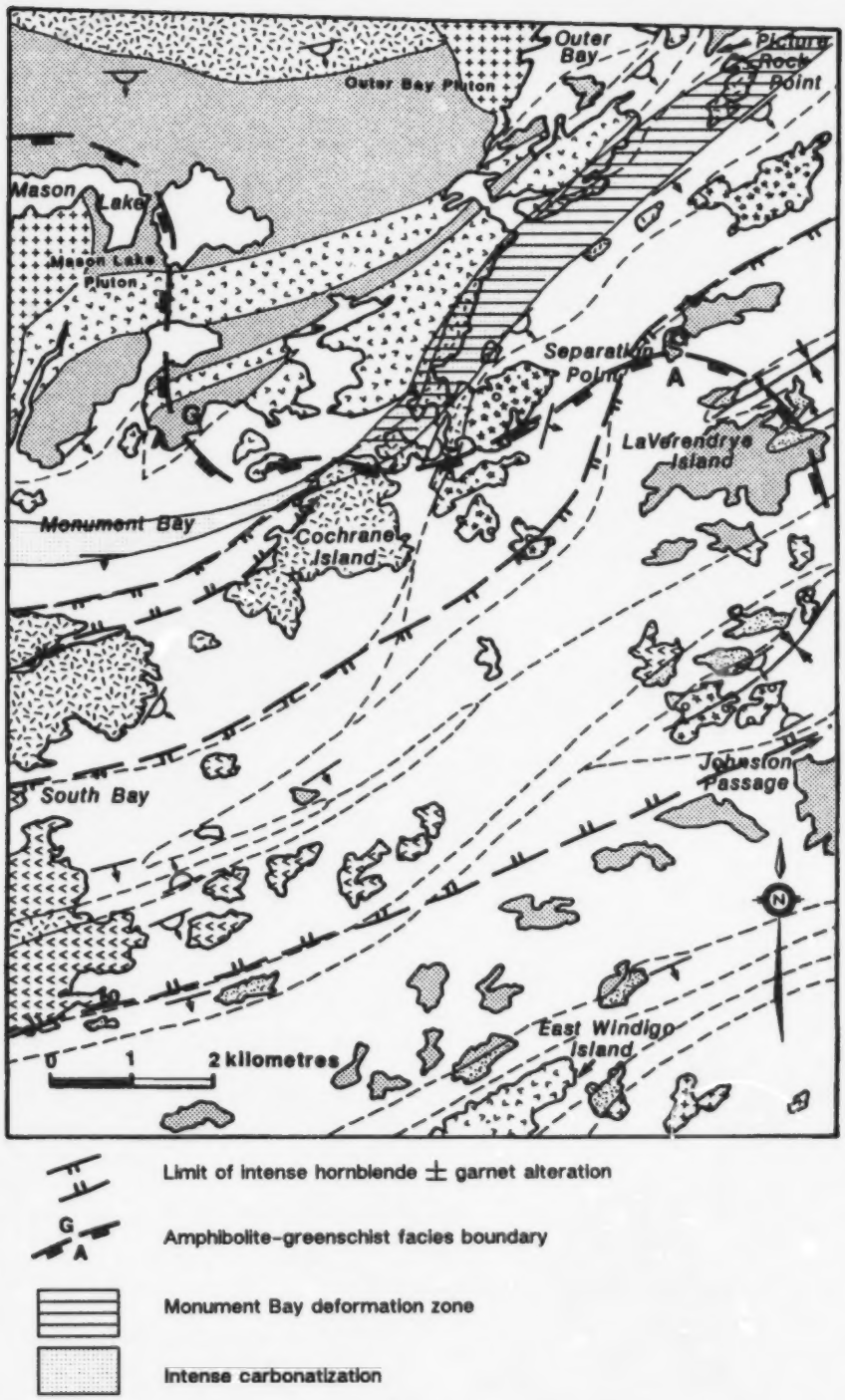

Figure 14. *Map showing the trace of the amphibolite-greenschist facies metamorphic isograd and the distribution of alteration and high strain zones, Monument Bay area.*

Photo 18. *Amphibolitized, intermediate plagioclase-phyric pillowed flow, Johnston Passage formation, south of La Vérendrye Island. Note relict plagioclase phenocrysts at left side of photo.*

wide thermal aureole has developed along the south flank of the Sabaskong Batholith (Johns 1987). These aureoles, 10 to 15 km wide, and the shallow dips of the supracrustal rocks along the north flank of the batholith, are consistent with the Sabaskong Batholith having broad, shallow dipping shoulders.

Epidote-hornblende hornfels aureoles have developed in country rocks adjacent to diabase dikes and the Mason Lake and Outer Bay granodiorite plutons. These aureoles are less than 1 km wide around the granitoid plutons and less than 20 m wide adjacent to diabase dikes. Up to 35 percent euhedral to subhedral epidote is closely associated with hornblende in these aureoles. Minor, local, retrograde metamorphism has developed in amphibolite facies rocks adjacent to quartz veins and pegmatite dikes, and along the Monument Bay deformation zone.

ALTERATION

Two alteration mineral assemblages are widespread in the Monument Bay area: chlorite ± carbonate alteration in greenschist facies rocks, and hornblende ± garnet ± carbonate alteration in amphibolite facies metavolcanics (*see* Figure 14). These two styles of alteration appear to have formed from hydrothermal fluids of similar composition; their contrasting mineralogy is the result either of formation under different pressure-temperature conditions, i.e., at peak and post-peak metamorphic conditions (cf. Andrews *et al.* 1986), or the elevation of a portion of a low-grade alteration assemblage to a higher metamorphic grade assemblage, i.e., alteration under pre-peak metamorphic conditions.

Replacement textures of hornblende after metamorphic biotite, and of hornblende overgrowths on hornblende pseudomorphing clinopyroxene phenocrysts, indicate that alteration occurred under peak to post-peak metamorphic conditions. The style of alteration is similar for both amphibolitization and carbonatization, and was controlled largely by preexisting permeability in the rock. Permeability is controlled by primary features such as rubbly flow tops and the fine-grained clastic matrix of coarse pyroclastics, and secondary features such as shear zones and fractures.

Alteration may be present as thin fracture fillings, or veins up to 25 cm wide; may selectively alter

Photo 19. *Intensely carbonatized, autoclastic, clinopyroxene-phyric mafic flow, Monument Bay formation, south of Outer Bay.*

matrix material (Photo 17); or may wholly alter a particular rock unit or series of units. Within the noted alteration zones, the degree of alteration is highly variable, ranging from rocks which are essentially unaltered to rocks which have been wholly replaced by alteration mineral assemblages.

Amphibole ± garnet alteration is best developed in a 2.5 km wide, northeast-trending swath which transects the central part of the map area (*see* Figure 14). The amphibole is black acicular hornblende, commonly occurring as 0.1 to 1 cm long needles randomly oriented in the plane of foliation. Garnet occurs as red, anhedral to euhedral porphyroblasts, 1 to 8 mm in diameter.

The compositional variability of the altered rocks is indicated by the variable abundance of garnet, even in rocks interpreted to have had similar magmatic compositions. Assemblages with high modal garnet, up to 30 percent, are presumably more iron-rich than those assemblages which contain minor, or no, garnet. This implies that the altering fluids were of variable iron content. The amphibolitization, as seen in thin section, is preserved as blue-green hornblende overgrowths on paler green horn-

blende pseudomorphs which are after clinopyroxene phenocrysts. Groundmass alteration is characterized by the presence of prismatic hornblende.

Plagioclase-phyric intermediate metavolcanics have been variably altered in the Johnston Passage area. Here, incipient alteration occurs as minor replacement of plagioclase phenocrysts by hornblende (Photo 18). With advanced alteration, the primary porphyritic texture is destroyed, resulting in an aphyric, fine-grained, mafic-looking rock with 50 to 60 percent prismatic hornblende and 35 to 40 percent fine-grained, granoblastic plagioclase and quartz.

Geochemically, hornblende alteration is characterized by the addition of CaO and MgO and the depletion of Al_2O_3, Na_2O and K_2O (*see* Table 5, sample number 0299, 0300). This apparent behaviour of Al_2O_3 indicates that Al_2O_3 is mobile under certain conditions, despite being considered immobile by many workers (e.g., MacLean and Kranidiotus 1987). The REEs remain relatively inert through this alteration, retaining pristine patterns characteristic of alkalic volcanics (*see* Figure 12).

Carbonate alteration is most intense northeast of Cochrane Island within the Monument Bay deformation zone. As with the amphibole alteration, carbonate alteration can occur selectively or in discrete veins, or can wholly replace a host rock (Photo 19). This alteration also occurs near the Monument Bay deformation zone to the southwest, on the amphibolite side of the metamorphic isograd, indicating either retrograde metamorphism or late alteration in this area. The dominant carbonate weathers tan brown, suggesting that ferroan dolomite is the carbonate species.

Economic Geology

INTRODUCTION

Recorded information concerning mineral exploration in the Monument Bay map area is limited to accounts of base metal exploration, during the 1970s, by Hudson Bay Exploration and Development Company Limited and Phelps Dodge Corporation of Canada Limited (Assessment Files, Resident Geologist's Office, Ontario Ministry of Northern Development and Mines, Kenora).

During the 1987 field program, 242 samples from mineralized and altered zones throughout the map area were collected for geochemical analysis. These analyses are presented in Table 11; sample locations are plotted on Figure 15. A number of these samples contain anomalous amounts of gold, base metals and indicator elements; these values are listed in Table 12.

At the commencement of the 1987 field season, there were no claims in good standing in the map area.

DESCRIPTION OF PROPERTIES

The following information has been obtained from the assessment files of the Resident Geologist's Office, Ontario Ministry of Northern Development and Mines, Kenora.

HUDSON BAY EXPLORATION AND DEVELOPMENT

Exploration for base metals was carried out by Hudson Bay Exploration and Development Company Limited (HBED) in the western part of the map area. In 1975, HBED diamond drilled three holes to test ground electromagnetic anomalies. A 93.6 m hole in the south part of Monument Bay encountered intermediate to felsic metavolcanics with numerous, thin (less than 1 m), pyrite-pyrrhotite-graphite intersections. On Cochrane Island, two holes, of 96 and 15.1 m respectively, intersected mafic and intermediate metavolcanics and minor porphyry dikes. Sulphide intersections were numerous but thin; typically, the drill log reports up to eight percent pyrrhotite with up to two percent pyrite over thicknesses of less than 1 m. No assay results were submitted with the logs from these drill holes.

PHELPS DODGE CORPORATION OF CANADA LIMITED (2)

Phelps Dodge Corporation (PDC) drilled one diamond drill hole, of 93.3 m length, in the northern part of the map area. This hole encountered mainly mafic metavolcanics, with two intersections of significant sulphides. The core contained 10 percent pyrite, 25 percent pyrrhotite and minor graphite from 41.3 to 46.3 m; and 5 percent pyrite with 20 percent pyrrhotite in graphite schist, from 74.8 to 77.1 m. A trace of chalcopyrite, with 10 percent pyrite, was present at 26.7 m. No assay results were submitted with the log from this drill hole.

DISCUSSION OF ASSAY RESULTS

Thirty-five samples from 24 separate locations contain greater than 100 ppb gold (*see* Table 12). This is the first indication that anomalous abundances of gold occur in this part of Lake of the Woods. Most of these anomalous values are associated with quartz-carbonate-pyrite veins in approximately east-trending steeply dipping shear zones. These shear zones have developed in both alkalic and tholeiitic, mafic metavolcanic rocks (*see* Photo 13). Individual, variably carbonatized shear zones are less than 2 m wide. However, the highest gold values, up to 52.3 ppm Au (*see* Table 12, map number 23), are associated, not with a discrete shear zone, but rather with thin (less than 0.5 cm wide) quartz-carbonate-chalcopyrite veinlets in fractured and locally sheared tholeiitic mafic metavolcanics.

Anomalous gold contents are associated with anomalous arsenic values in east-trending shear zones, or with anomalous base metal values in brittlely fractured mafic metavolcanics (*see* Table 12).

GUIDELINES FOR MINERAL EXPLORATION

BASE METALS

Base metal exploration should focus on felsic metavolcanics west of Outer Bay. Here mono- to heterolithic quartz-plagioclase porphyry pyroclastics locally contain 5 to 10 mm diameter clasts of pyrrhotite and pyrite. The change from mono- to heterolithic proclastics may be related to reworking of the brecciated carapace of a felsic dome. The sulphide clasts may be reworked exhalative sulphides. This is a classic geological environment for base metal deposition (e.g., Franklin *et al.* 1981).

GOLD

Gold exploration should be directed primarily to two areas: the Monument Bay deformation zone within mafic metavolcanics of the Cochrane Island and Separation Point formations, and the region of extensive hornblende ± garnet alteration further south (*see* Figure 14).

The amphibolite-greenschist facies boundary crosses both of these features at near right angles and should direct initial exploration. A number of

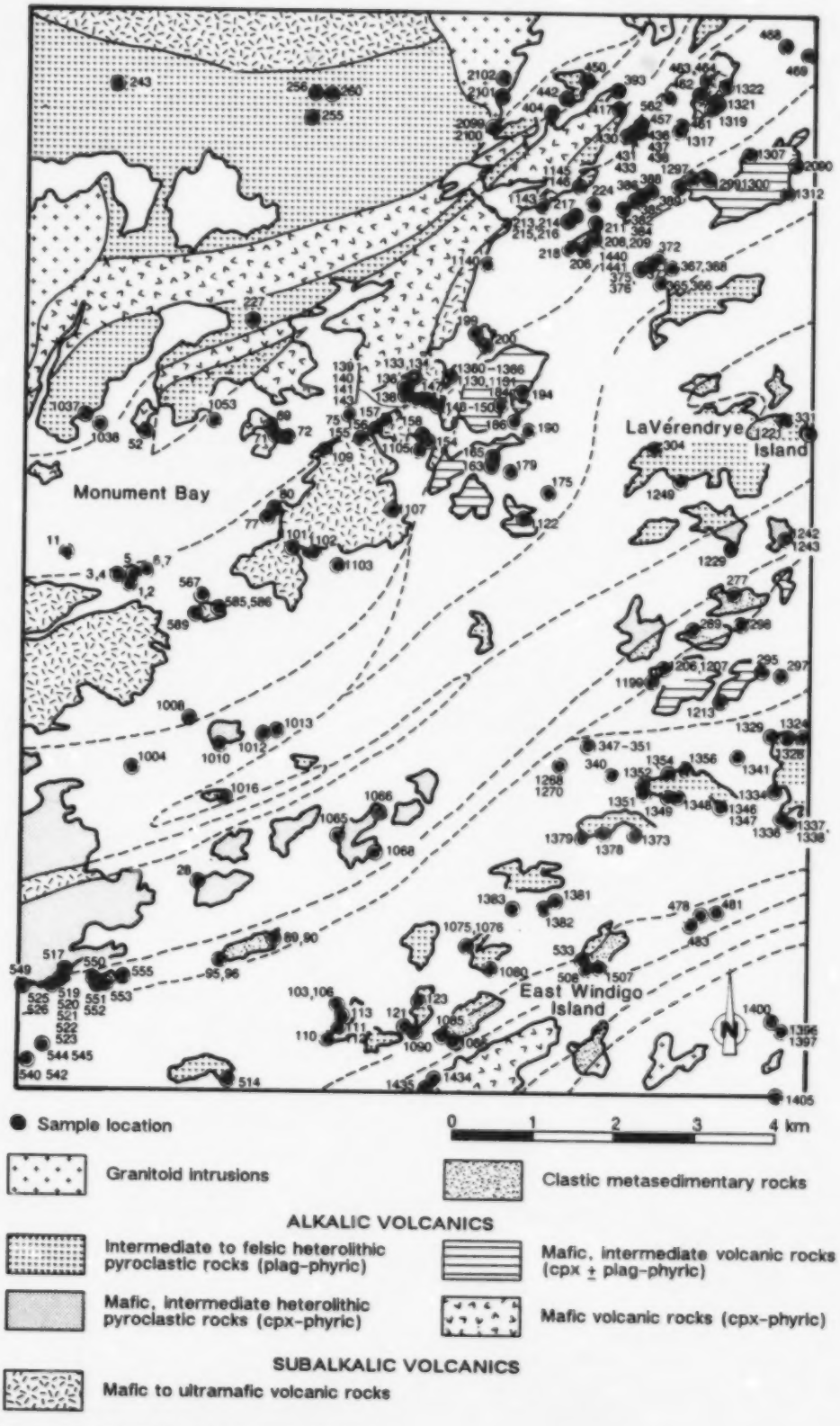

Figure 15. *Assay sample locations, Monument Bay area.*

samples collected from shear zones in the mafic metavolcanics contain greater than 100 ppb gold (*see* Table 12). These anomalous results are, in part, stratigraphically controlled, occurring intermittently along the greater than 10 km strike length of the tholeiitic mafic metavolcanics of the Cochrane Island formation. The highest gold values (up to 52.3 ppm Au) are associated with quartz-carbonate-chalcopyrite veinlets in fractured and sheared mafic metavolcanics northeast of Cochrane Island.

Favourable host rocks (mafic metavolcanics), structure (shear zones), alteration (carbonatization), and metamorphic conditions (at or near the amphibolite-greenschist facies transition) have provided a very attractive area in which to explore for precious metals (e.g., Groves *et al.* 1985).

Sulphides occur in discrete zones within altered (hornblende ± garnet) intermediate to felsic metavolcanics west of Johnston Passage. Samples collected from these sulphide zones contain only background values of gold. However, this alteration zone should be explored, especially to the northeast, on the greenschist side of the amphibolite-greenschist isograd, where conditions may be more favourable for gold deposition (e.g., Groves *et al.* 1985).

TABLE 11. ASSAY RESULTS (all values in ppm, except as noted).

	0001	001D	0002	0003	003D	003D
Ag	<2	<2	<2	<2		
As	7	8.50	15.50	1		
Au	8ppb	9ppb	7ppb	70ppb	65ppb	75ppb
Cu	238	240	75	260		
Pb	18	20	34	<10		
Zn	1300	1315	850	1540		

	0004	004D	004D	0005	005D	005D
Ag	<2			<2		
As	2			3.50		
Au	9999ppb	110ppb	460ppb	105ppb	105ppb	100ppb
Cu	108			164		
Pb	<10			<10		
Zn	295			2420		

	0006	0007	0011	0028	0052	0069
Ag	<2	<2	<2	<2	<2	<2
As	1	2	<1	<1	2	1
Au	16ppb	9ppb	<2ppb	3ppb	<2ppb	<2ppb
Cu	510	51	208	268	23	18
Pb	23	<10	<10	<10	<10	<10
Zn	2680	138	78	143	14	28

	0071	0072	0075	0077	0080	0089
Ag	<2	<2	<2	<2	<2	<2
As	51	1.50	1	<1	<1	1
Au	<2ppb	<2ppb	<2ppb	3ppb	<2ppb	<2ppb
Cu	25	143	9	260	158	63
Pb	54	<10	<10	<10	<10	11
Zn	84	81	<10	105	405	235

	0090	0095	0096	0103	0106	0106D
Ag	<2	<2	<2	<2	<2	<2
As	<1	1.50	<1	2.50	1	1
Au	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb
Cu	42	24	22	19	39	39
Pb	<10	10	11	<10	<10	<10
Zn	155	66	60	48	47	47

Complete sample numbers in the format 87MGM-xxxx.
"D" in sample number signifies a duplicate analysis of elements listed.

TABLE 11. Continued.

	0110	0111	0112	0113	0121	0123
Ag	<2	<2	<2	<2	<2	<2
As	<1	1	<1	1.50	10.50	2
Au	<2ppb	<2ppb	<2ppb	10ppb	<2ppb	<2ppb
Cu	19	13	12	21	11	12
Pb	10	11	<10	13	<10	<10
Zn	42	24	55	52	14	20

	0133	0134	0136	0138	0138D	0140
Ag	<2	<2	<2	<2	<2	<2
As	<1	<1	3.50	1.50	1.50	<1
Au	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb
Cu	43	10	10	131	129	77
Pb	<10	<10	<10	<10	<10	<10
Zn	70	51	106	81	82	108

	0141	0143	0147	0148	148A	0149
Ag	<2	<2	<2	<2	<2	<2
As	1	<1	<1	<1	<1	<1
Au	15ppb	2ppb	<2ppb	<2ppb	2ppb	11ppb
Cu	27	117	215	63	424	508
Pb	10	<10	<10	<10	16	31
Zn	62	81	165	155	434	1363

	0150	0154	0155	0156	0157	0158
Ag	<2	<2	<2	<2	<2	<2
As	<1	<1	20	<1	1	1
Au	<2ppb	2ppb	4ppb	<2ppb	<2ppb	10ppb
Cu	129	116	33	33	38	123
Pb	13	92	<10	<10	<10	<10
Zn	218	71	115	118	120	243

	0158D	0163	0165	0175	0179	0184
Ag	<2	<2	<2	<2	<2	<2
As	1	<1	<1	<1	<1	7.50
Au	9ppb	<2	2ppb	<2	2ppb	10ppb
Cu	122	69	89	89	38	188
Pb	<10	<10	<10	<10	<10	<10
Zn	240	158	258	63	68	271

	0186	0190	0194	0199	0200	0206
Ag	<2	2	<2	<2	<2	<2
As	<1	<1	<1	<1	<1	<1
Au	<2	60ppb	6ppb	3ppb	<2	40ppb
Cu	46	17	371	105	16	22
Pb	<10	<10	<10	<10	<10	<10
Zn	59	22	52	36	156	39

	0208	0209	0211	0213	0214	0215
Ag	<2	<2	<2	<2	<2	<2
As	25	12	3	3	7	4.50
Au	65ppb	870ppb	65ppb	12ppb	250ppb	100ppb
Cu	44	8	203	193	48	20
Pb	<10	<10	<10	<10	<10	<10
Zn	11	40	21	45	35	15

Complete sample numbers in the format 87MGM-xxxx.
"D" in sample number signifies a duplicate analysis of elements listed.

TABLE 11. Continued.

	0216	0217	0218	0224	0227	0243
Ag	<2	<2	<2	<2	<2	<2
As	8	3	3.50	8	2.50	10
Au	160ppb	335ppb	18ppb	55ppb	2ppb	140ppb
Cu	18	329	25	9	24	13
Pb	<10	<10	<10	<10	<10	16
Zn	11	22	31	13	48	24

	0255	0256	0260	0277	0289	0295
Ag	<2	<2	<2	<2	<2	<2
As	<1	1.50	<1	1	25	<1
Au	<2	2ppb	<2	5ppb	15ppb	<2
Cu	20	10	22	45	80	14
Pb	<10	<10	<10	<10	<10	<10
Zn	34	42	59	<10	24	79

	0297	0298	0304	0331	0340	0347
Ag	<2	<2	<2	<2	<2	<2
As	1.50	<1	<1	<1	<1	1
Au	<2	<2	9ppb	2ppb	4ppb	2ppb
Cu	35	53	61	62	83	49
Pb	<10	<10	<10	<10	<10	<10
Zn	34	91	73	745	80	198

	0348	0349	0350	0351	0365	0366
Ag	<2	<2	<2	<2	<2	<2
As	1	1	33	35	<1	<1
Au	3ppb	4ppb	14ppb	25ppb	23ppb	10ppb
Cu	16	44	12	70	90	15
Pb	<10	<10	<10	<10	<10	<10
Zn	54	67	20	98	39	18

	0367	367D	367D	0368	368D	368D
Ag	<2			<2		
As	2			1		
Au	120ppb	130ppb	120ppb	90ppb	85ppb	95ppb
Cu	9			25		
Pb	<10			<10		
Zn	12			73		

	0372	372D	372D	0375	375D	375D
Ag	<2			12		
As	3			15		
Au	400ppb	415ppb	400ppb	215ppb	220ppb	210ppb
Cu	9			1230		
Pb	<10			<10		
Zn	21			26		

	0376	376D	376D	0377	377D	377D
Ag	<2			<2		
As	1			2		
Au	160ppb	160ppb	165ppb	330ppb	330ppb	330ppb
Cu	13			51		
Pb	<10			<10		
Zn	40			27		

Complete sample numbers in the format 87MGM-xxxx.
"D" in sample number signifies a duplicate analysis of elements listed.

TABLE 11. Continued.

	0382	382D	382D	0384	384D	384D
Ag	<2			<2		
As	11.50			3.50		
Au	225ppb	225ppb	225ppb	250ppb	255ppb	245ppb
Cu	18			49		
Pb	<10			<10		
Zn	33			49		

	0385	385D	385D	0386	386D	386D
Ag	2			<2		
As	6			2.50		
Au	1680ppb	2000ppb	1360ppb	90ppb	100ppb	85ppb
Cu	162			27		
Pb	<10			<10		
Zn	58			53		

	0388	388D	388D	0389	389D	389D
Ag	<2			<2		
As	4			1		
Au	585ppb	590ppb	580ppb	150ppb	165ppb	140ppb
Cu	20			16		
Pb	<10			<10		
Zn	72			78		

	0393	0404	0417	0430	0431	0433
Ag	<2	<2	<2	<2	<2	<2
As	<1	63	2	1.50	2.50	5
Au	2ppb	4ppb	14ppb	3ppb	12ppb	755ppb
Cu	41	77	175	41	290	460
Pb	<10	<10	<10	<10	<10	<10
Zn	49	63	85	86	49	<10

	433D	433D	0436	436D	436D	0437
Ag			<2			<2
As			5.50			1
Au	700ppb	810ppb	530ppb	420ppb	640ppb	24ppb
Cu			26			32
Pb			<10			<10
Zn			<10			<10

	0438	0442	0442D	0450	0450D	0457
Ag	<2	<2	<2	11	10	<2
As	1	6.50	6	25	26	1
Au	11ppb	<2ppb	<2ppb	6ppb	7ppb	2ppb
Cu	15	45	43	61	61	56
Pb	<10	149	145	880	855	<10
Zn	10	420	413	190	180	89

	0457D	0461	0461D	0462	0462D	0463
Ag	<2	<2	<2	<2	<2	<2
As	1	5	5	1	1	5
Au	4ppb	23ppb	22ppb	<2ppb	<2ppb	23ppb
Cu	61	95	95	14	15	60
Pb	<10	<10	<10	<10	<10	<10
Zn	88	67	69	14	16	19

Complete sample numbers in the format 87MGM-xxxx.
"D" in sample number signifies a duplicate analysis of elements listed.

TABLE 11. Continued.

	0464	0468	0469	469D	469D	0478
Ag	<2	<2	3			<2
As	1.50	1.50	1.50			1
Au	10ppb	<2ppb	170ppb	170ppb	170ppb	11ppb
Cu	28	100	89			51
Pb	<10	<10	<10			<10
Zn	16	28	44			72

	0481	0488	0507	0508	0514	0517
Ag	<2	2	<2	<2	<2	<2
As	8.50	2.50	3	47	1	<1
Au	2ppb	<2ppb	13ppb	<2ppb	3ppb	5ppb
Cu	42	99	25	19	34	52
Pb	<10	<10	12	22	11	<10
Zn	81	128	57	35	27	15

	0519	0520	0521	0522	0523	0525
Ag	<2	2	<2	<2	<2	<2
As	2.50	1.50	1	1	90	<1
Au	<2ppb	5ppb	<2ppb	4ppb	13ppb	<2ppb
Cu	38	89	31	50	39	73
Pb	<10	<10	<10	<10	<10	<10
Zn	240	147	91	112	54	94

	0526	0533	0540	0542	0544	0545
Ag	<2	<2	<2	<2	<2	<2
As	<1	2.50	1	<1	<1	<1
Au	<2ppb	<2ppb	<2ppb	2ppb	<2ppb	<2ppb
Cu	160	23	24	37	12	15
Pb	<10	<10	<10	<10	<10	<10
Zn	198	116	93	73	80	68

	0549	0550	0551	0552	0553	0555
Ag	<2	<2	<2	<2	<2	<2
As	<1	3.50	<1	3	<1	1
Au	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	4ppb
Cu	114	36	43	60	67	39
Pb	<10	<10	<10	<10	21	<10
Zn	122	85	63	24	88	137

	0562	0567	567D	567D	0585	0586
Ag	<2	2			<2	<2
As	1.50	<1			2	1.50
Au	8ppb	120ppb	100ppb	140ppb	<2	<2
Cu	51	78			23	33
Pb	<10	<10			<10	<10
Zn	84	111			42	33

	0589	1004	1008	1010	1012	1013	1016
Ag	<2	<2	<2	<2	<2	<2	<2
As	1.50	<1	<1	<1	2	<1	<1
Au	2 B	<2ppb	<2ppb	<2ppb	11ppb	<2ppb	4ppb
Cu	110	40	47	12	205	<5	9
Pb	<10	<10	<10	<10	<10	<10	<10
Zn	325	86	50	99	155	111	32

Complete sample numbers in the format 87MGM-xxxx.
"D" in sample number signifies a duplicate analysis of elements listed.

TABLE 11. Continued.

	1038	1053	1065	1066	1068	1075
Ag	<2	<2	<2	<2	<2	<2
As	1	1.50	1.50	<1	2.50	1.50
Au	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb
Cu	37	95	100	156	8	12
Pb	27	16	<10	34	<10	<10
Zn	20	95	114	900	25	19

	1076	1080	1085	1086	1090	1091
Ag	<2	<2	<2	<2	<2	<2
As	15	11	3.50	<1	2	<1
Au	<2ppb	2ppb	<2ppb	<2ppb	5ppb	2ppb
Cu	26	10	16	52	63	31
Pb	10	<10	10	13	<10	<10
Zn	16	180	220	78	121	32

	1101	1101D	1101D	1102	1102D	1102D
Ag	<2			<2		
As	1			<1		
Au	100ppb	115ppb	90ppb	1000ppb	960ppb	1050ppb
Cu	53			305		
Pb	<10			<10		
Zn	41			155		

	1103	1103D	1105	1107	1122	1130
Ag	<2	<2	<2	<2	<2	<2
As	<1	<1	<1	<1	<1	2
Au	21ppb	22ppb	3ppb	2ppb	<2	290ppb
Cu	710	710	169	96	87	262
Pb	<10	<10	<10	<10	<10	<10
Zn	398	400	325	49	54	32

	1131	1140	1143	1145	1146	1199
Ag	38	<2	<2	<2	<2	<2
As	<1	3	2.50	1	1.50	<1
Au	52.30	13ppb	39ppb	4ppb	24ppb	<2
Cu	1 P	46	152	85	30	41
Pb	<10	<10	<10	<10	44	<10
Zn	216	<10	21	70	16	78

	1206	1207	1213	1221	1229	1242
Ag	<2	<2	<2	<2	<2	<2
As	<1	<1	<1	1	<1	<1
Au	<2	<2	7ppb	2ppb	7ppb	27ppb
Cu	5	5	147	31	223	54
Pb	<10	<10	<10	<10	12	<10
Zn	13	10	284	56	146	98

	1243	1249	1268	1270	1297	1299
Ag	<2	<2	<2	<2	<2	<2
As	<1	<1	<1	1.50	1.50	19.50
Au	2ppb	3ppb	<2ppb	<2ppb	<2ppb	5ppb
Cu	31	135	15	11	37	188
Pb	<10	<10	<10	<10	<10	<10
Zn	125	163	63	30	52	113

Complete sample numbers in the format 87MGM-xxxx.
"D" in sample number signifies a duplicate analysis of elements listed.

TABLE 11. Continued.

	1300	1300D	1307	1307D	1312	1312D
Ag	<2	<2	<2	<2	<2	<2
As	2.50	2.50	2.50	2.50	3	3
Au	3ppb	3ppb	24ppb	24ppb	3ppb	3ppb
Cu	124	122	1990	1980	27	27
Pb	<10	<10	<10	<10	<10	<10
Zn	40	38	203	203	92	90

	1317	1319	1321	1322	1324	1328
Ag	<2	<2	<2	<2	<2	<2
As	1	70	5.50	1	1	<1
Au	<2ppb	<2ppb	10ppb	<2ppb	2ppb	<2ppb
Cu	18	65	23	111	10	68
Pb	<10	<10	<10	<10	28	<10
Zn	59	69	51	515	71	20

	1329	1334	1336	1336D	1336D	1337
Ag	2	<2	3			8
As	4.50	<1	8			11
Au	16ppb	4ppb	60ppb	60ppb	65ppb	235ppb
Cu	25	40	37			36
Pb	<10	<10	16			380
Zn	10	29	43			333

	1337D	1337D	1338	1341	1346	1347
Ag			2	<2	<2	<2
As			1.50	1.50	<1	<1
Au	230ppb	240ppb	19ppb	6ppb	6ppb	6ppb
Cu			21	23	8	93
Pb			<10	<10	<10	<10
Zn			92	55	18	72

	1348	1349	1351	1352	1354	1356
Ag	<2	<2	2	2	<2	<2
As	2	2	3.50	10	<1	15
Au	13ppb	5ppb	19ppb	8ppb	<2ppb	26ppb
Cu	16	21	22	23	27	7
Pb	<10	<10	42	20	16	16
Zn	32	31	32	51	103	12

	1360	1360D	1360D	1361	1361D	1361D
Ag	7			19		
As	<1			<1		
Au	4355ppb	4180ppb	4530ppb	6815ppb	6480ppb	7150ppb
Cu	4050			1.24 P		
Pb	<10			<10		
Zn	263			305		

	1362	1362D	1362D	1363	1363D	1363D
Ag	2			8		
As	<1			<1		
Au	4145ppb	4120ppb	4170ppb	1400ppb	1335ppb	1470ppb
Cu	1040			4225		
Pb	<10			<10		
Zn	180			195		

Complete sample numbers in the format 87MGM-xxxx.
"D" in sample number signifies a duplicate analysis of elements listed.

TABLE 11. Continued.

	1364	1364D	1364D	1364D	1365	1365D
Ag	24				32	
As	<1				1	
Au	9999ppb	6600ppb	4230ppb	4820ppb	9999ppb	12.70
Cu	1.65 P				710	
Pb	<10				<10	
Zn	313				103	

	1365D	1365D	1366	1366D	1366D	1366D
Ag			2			
As			<1			
Au	15.70	18.80	9999ppb	11.50	9.30	9.20
Cu			610			
Pb			<10			
Zn			158			

	1373	1378	1379	1381	1382	1396
Ag	<2	<2	<2	<2	<2	<2
As	3.50	2.50	2.50	4	54	2.50
Au	<2ppb	<2ppb	<2ppb	4ppb	<2ppb	<2ppb
Cu	5	129	36	46	63	133
Pb	<10	<10	<10	<10	15	22
Zn	10	28	210	35	17	65

	1397	1397D	1400	1400D	1405D	2090
Ag	<2	<2	<2	<2	2	
As	1.50	1.50	<1	<1	10	
Au	<2ppb	<2ppb	<2ppb	<2ppb	2ppb	
Cu	38	37	5	5	90	
Pb	23	22	<10	<10	<10	
Zn	36	35	20	21	109	

	2090	2090D	2090D	2090D	2099	2100
Ag	<2				<2	<2
As	<1				<1	<1
Au	9999ppb	85ppb	2150ppb	16ppb	11ppb	16ppb
Cu	11				1390	1475
Pb	<10				38	25
Zn	35				20	19

	2101	2102
Ag	<2	9
As	<1	<1
Au	6ppb	22ppb
Cu	795	1155
Pb	51	210
Zn	15	<10

Complete sample numbers in the format 87MGM-xxxx.
"D" in sample number signifies a duplicate analysis of elements listed.

TABLE 12. ANOMALOUS ASSAY RESULTS[a,b].

Map No.[c]	Au	Ag	As	Cu	Zn
1	500	nd	2.0	108	295
2	105	nd	3.5	164	2420
3a	870	nd	12.0	8	40
3b	400	nd	11.0	14	23
4a	250	nd	7.0	48	35
4b	100	nd	4.5	20	15
4c	160	nd	8.0	18	11
5	335	nd	3.0	329	22
6	140	nd	10.0	13	24
7	120	nd	2.0	9	12
8	400	nd	3.0	9	21
9	215	12	15.0	1230	26
10	160	nd	1.0	13	40
11	330	nd	2.0	51	27
12	225	nd	11.5	18	33
13	250	nd	3.5	49	49
14	1680	2	6.0	162	58
15	585	nd	4.0	20	72
16	150	nd	1.0	16	78
17	755	nd	5.0	460	nd
18	530	nd	5.5	26	nd
19	170	3	1.5	89	44
20	120	2	nd	78	111
21	100	nd	1.0	53	41
22	1000	nd	nd	305	155
23a	290	nd	2.0	260	32
23b	52.3ppm	38	nd	1.08%	216
23c	4355	7	nd	4050	263
23d	6815	19	nd	1.24%	305
23e	4145	2	nd	1040	180
23f	1400	8	nd	4225	195
23g	5200	24	nd	1.65%	313
23h	15.7ppm	32	1.0	710	103
23i	10.0ppm	2	nd	610	158
24	235	8	11.0	36	333

nd–not detected.

[a] *Results in ppm (Ag, As, Cu, Zn), ppb (Au), except as noted.*

[b] *Pb analyses: all samples "nd" except 6 (16 ppm) and 24 (380 ppm)*

[c] *Map No. refers to location as annotated on Map 2524.*

References

Andrews, A.J., Hugon, H., Durocher, M., Corfu, F. and Lavigne, M.J. 1986. The Anatomy of a gold-bearing greenstone belt: Red Lake, northwestern Ontario, Canada; *in* Proceedings of Gold '86, An International Symposium on the Geology of Gold, p.3-22.

Arculus, R.J. and Wills, K.J.A. 1980. The petrology of plutonic blocks and inclusions from the Lesser Antilles Island arc; Journal of Petrology, v.21, p.743-799.

Arndt, N.T. and Nesbitt, R.W. 1984. Magma mixing in komatiitic lavas from Munro Township, Ontario; *in* Archean Geochemistry, Springer-Verlag, Berlin, 114p.

Ayer, J.A. 1988. Geology of the Falcon Island area, Lake of the Woods, District of Kenora; *in* Summary of Field Work and Other Activities 1988, Ontario Geological Survey, Miscellaneous Paper 141, p.132-137.

Ayer, J.A. and Gil, K.M. 1986. Precambrian geology, Rat Portage Bay, District of Kenora; Ontario Geological Survey, Preliminary Maps P.2966 and P.2967, scale 1:15 840.

Ayer, J.A., Gil, K.M. and McCurdy, M. 1985. Precambrian geology, Bigstone Bay, District of Kenora; Ontario Geological Survey, Preliminary Maps P.2830 and P.2831, scale 1:15 840.

Ayer, J.A., MacFie, R.I. and Buck, S. 1987. Geology of the Chisholm Island area, Lake of the Woods, District of Kenora; *in* Summary of Field Work and Other Activities 1987, Ontario Geological Survey, Miscellaneous Paper 137, p.39-44.

Ayer, J.A. and Sweeney, J.M. 1936. Geology of the Clearwater Bay area, Lake of the Woods, District of Kenora; *in* Summary of Field Work and Other Activities 1986, Ontario Geological Survey, Miscellaneous Paper 132, p.37-40.

Berger, B.R. 1987. Laval and Hartman townships area, District of Kenora; *in* Summary of Field Work and Other Activities 1987, Ontario Geological Survey, Miscellaneous Paper 137, p.84-89.

Blackburn, C.E. 1981. Kenora-Fort Frances, Kenora and Rainy River districts; Ontario Geological Survey, Map 2443, scale 1:253 440.

——1982. Geology of the Manitou Lakes area, District of Kenora (stratigraphy and petrochemistry); Ontario Geological Survey, Report 223, 61p.

Brooks, C., Ludden, J., Pigeon, Y. and Hubregtse, J.J.M.W. 1982. Volcanism of shoshonite to high-K andesite affinity in an Archean arc environment, Oxford Lake, Manitoba; Canadian Journal of Earth Sciences, v.19, p.55-67.

Buck, S. 1986. Metallogenic studies in the Kakagi-Rowan Lakes area, District of Kenora; *in* Summary of Field Work and Other Activities 1986, Ontario Geological Survey, Miscellaneous Paper 132, p.261-265.

Cooke, D.L. and Moorehouse, W.W. 1969. Timiskiming volcanism in the Kirkland Lake area, Ontario, Canada; Canadian Journal of Earth Sciences, v.6, p.117-132.

Corkery, M.T. and Cameron, H.D.M. 1987. Cross Lake supracrustal investigations; *in* Report of Field Activities 1987, Manitoba Energy and Mines, Minerals Division, p.135-136.

Davies, J.C. 1983. Western Peninsula, District of Kenora; Ontario Geological Survey, Map 2423, scale 1:31 680.

Fisher, R.V. and Schmincke, H.-U. 1984. Pyroclastic Rocks; Springer-Verlag, Berlin, 472p.

Franklin, J.M., Lydon, J.W. and Sangster, D.F. 1981. Volcanic-associated massive sulphide deposits; Economic Geology, 75th Anniversary Volume, p.485-627.

Gill, J.B. 1981. Orogenic andesites and plate tectonics; Springer-Verlag, Berlin, 390p.

Gill, J.B. and Whelan, P. 1989. Early rifting of an oceanic island arc (Fiji) produced shoshonitic to tholeiitic basalts; Journal of Geophysical Research, v.94, p.4561-4578.

Greer, L. 1931. Geology of the Shoal Lake (west) area, District of Kenora; Ontario Department of Mines, Annual Report, 1930, v.39, pt.3, p.42-56.

Groves, D.I., Phillips, G.N., Ho, S.E. and Houstoun, S.M. 1985. The nature, genesis and regional controls on gold mineralization in Archaean greenstone belts of the western Australian Shield: A brief review; Transactions of the Geological Society of South Africa, v.88, p.135-148.

Halls, H.C. 1986. Paleomagnetism, structure, and longitudinal correlation of Middle Precambrian dikes from northwestern Ontario and Minnesota; Canadian Journal of Earth Sciences, v.23, p.142-157.

Irvine, T.N. and Baragar, W.R.A. 1971. A guide to the classification of the common volcanic rocks; Canadian Journal of Earth Science, v.8, p.523-549.

Jensen, L.S. 1976. A new cation plot for classifying subalkalic volcanic rocks; Ontario Department of Mines, Miscellaneous Paper 66, 22p.

Johns, G.W. 1987. Geology of the Rainy River area, District of Rainy River; *in* Summary of Field Work and Other Activities 1987, Ontario Geological Survey, Miscellaneous Paper 137, p.45-48.

Joplin, G.A. 1968. The shoshonite association: a review; Journal of the Geological Society of Australia, v.15, p.275-294.

Kay, R.W. and Gast, P.W. 1973. The rare earth content and origin of alkali-rich basalts; Journal of Geology, v.81, p.653-682.

Lawson, A.C. 1885. Report on the geology of the Lake of the Woods region with special reference to the Keewatin (Huronian?) belt of the Archean rocks; Geology and Natural History Survey of Canada, Annual Report for 1885, v.1, pt.CC, 151p.

Mackenzie, D.E. and Chappell, B.W. 1972. Shoshonitic and calc-alkaline lavas from the highlands of Papua New Guinea; Contributions to Mineralogy and Petrology, v.35, p.50-62.

MacLean, W.H. and Kranidiotus, P. 1987. Immobile elements as monitors of mass transfer in hydrothermal alteration: Phelps Dodge massive sulfide deposit, Matagami, Quebec; Economic Geology, v.82, p.951-962.

Morrice, M.G. 1988, Geology of the Northwest Angle Inlet area; Ontario Geological Survey, Open File Report 5683, 139p.

Morrice, M.G. and Gill, J.B. 1986. Spatial patterns in the mineralogy of island arc magma series: Sangihe arc, Indonesia; Journal of Volcanology and Geothermal Research, v.29, p.311-353.

Morrice, M.G. and MacMaster, G.A. 1987. Precambrian geology, Northwest Angle Inlet area, District of Kenora; Ontario Geological Survey, Preliminary Map P.3084, scale 1:15 840.

Ontario Department of Mines-Geological Survey of Canada 1962. Falcon Island, Ontario; Ontario Department of Mines-Geological Survey of Canada, Map 1185G, aeromagnetic series, scale 1:63 360.

Shegelski, R.J. 1980. Archean cratonization, emergence and red bed development, Lake Shebandowan Area, Canada; Precambrian Research, v.12, p.331-347.

Smith, P.M. 1987. Geology of the High Lake area, District of Kenora; *in* Summary of Field Work and Other Activities 1987, Ontario Geological Survey, Miscellaneous Paper 137, p.61-65.

Southwick, D.L. and Day, W.C. 1983. Geology and petrology of Proterozoic mafic dikes, north-central Minnesota and western Ontario; Canadian Journal of Earth Sciences, v.20, p.622-638.

Southwick, D.L. and Halls, H.C. 1987. Compositional characteristics of the Kenora-Kabetogama dike swarm (Early Proterozoic), Minnesota and Ontario; Canadian Journal Earth Sciences, v.24, p.2197-2205.

Streckeisen, A. 1976. To each plutonic rock its proper name; Earth Science Reviews, v.12, p.1-33.

Teal, P.R. 1979. Stratigraphy, sedimentology, volcanology, and development of the Archean Manitou Group, Northwestern Ontario, Canada; unpublished PhD thesis, McMaster University, Hamilton, Ontario.

Trowell, N.F. 1986. Geology of the Gibi Lake area, District of Kenora; Ontario Geological Survey, Open File Report 5629, 153p.

Williams, H. and McBirney, A.R. 1979. Volcanology; Freeman, Cooper and Co., San Francisco, 397p.

Wilson, H.D.B., Morrice, M.G. and Ziehlke, D.V. 1974. Archean continents; Geoscience Canada, v.1, p.12-20.

MAPS
NOT
FILMED

CARTES
OMISES